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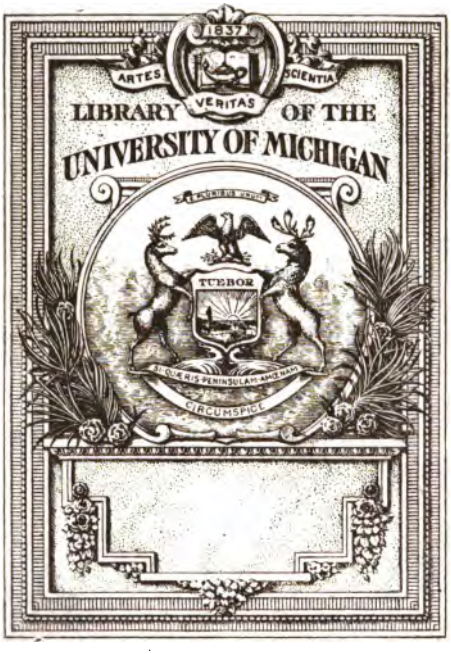
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PROFESSIONAL PAPERS

OF THE

Gt. Brit.

CORPS OF ROYAL ENGINEERS.

ROYAL ENGINEER INSTITUTE

OCCASIONAL PAPERS,

VOL. I.

1877.

Printed for
THE ROYAL ENGINEER INSTITUTE, AT THE S.M.E., CHATHAM.

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ERRATA.

Page 15, last line, for *rain* read *range.*

„ 17, second line, for *Service Sights , a calculation which*, read *Service Sights with calculations, which*

„ 135, top line should come after present third line, *No.* 3 *carries—*

„ 135, line 25, for *timber piece* read *timber pier.*

PREFACE.

THE completion of the 4th Number and the 1st Volume of the *Occasional Papers*, published by the R.E. Institute, and the commencement thereby of a new series of the *R.E. Professional Papers*, seems a fit opportunity for a brief review of the history of our professional publications.

The *Professional Papers* were commenced in 1837 at the suggestion of the late Sir William Denison, then a lieutenant, who, at the request of a meeting of the officers of the Corps, undertook the duty of editor, and performed this duty until 1847, when he was appointed Lieutenant-Governor of Van Dieman's Land (Tasmania). Eight quarto volumes had then been published, and so successful were they considered to be, that a piece of plate was presented to Sir W. Denison by the subscribers, with the following inscription :—

"Presented by his Brother Officers who attended the meeting of the 23rd September, 1846, to Captain Sir William Denison, Royal Engineers, as a token of grateful remembrance, that to him alone they are indebted for having originated the diffusion of individual experience by means of the *Professional Papers*, which he has continued to conduct for a period of ten years, until he was appointed to the Government of Van Dieman's Land."

The late Sir Henry James, then Captain James, edited the 9th Volume for Sir W. Denison, and Colonel Lewis and Captain J. Williams were appointed joint editors for the future, and were requested at the Annual Corps Meeting, held on the 1st February, 1847, to submit a plan of publication to an adjourned meeting, which was held on the 23rd of the same month. At this meeting it was determined to undertake two separate and distinct publications; the one to be of large octavo size and to be called the *Corps Papers*, to comprise subjects which might be of little interest to the public, or to civil engineers and architects; the other to be a continuation of the existing *Professional Papers*, and to embrace

matters of general interest to the public, the civil engineer, and architect, as well as to the military engineer. The *Corps Papers* were to be published by subscription, but the *Professional Papers* were to be placed in the hands of the publisher, Mr. Weale, with certain privileges to the libraries and officers of the Corps in the supply of copies.

During the next three years the joint editors published three numbers of the *Corps Papers* which formed one volume, and Volume X. of the *Professional Papers*; but whilst the supply of matter for the *Corps Papers* was ample, that for the *Professional Papers* was very insufficient, and the publisher declined to continue the work on account of the expense.

At the Annual Corps Meeting held in February, 1851, it was therefore determined :—

1. That the quarto form should cease to be published.

2. That the octavo form should be continued, comprising the objects of both works.

3. That contributions should be confined to the Royal Engineers, and the Engineer Department of the East India Company's Service.

4. That the title of the work should be, under the new form, *Professional Papers, New Series*, and termed, "Papers on subjects connected with the duties of the Corps of Royal Engineers," contributed by members of the Royal and East India Company's Engineers, and edited by a Committee of Royal Engineers.

5. That the new work, under the above title, should be open to the public, and bound with green to represent the quarto volumes in a smaller shape.

Major-General Lewis and Captain Williams continued to act as joint editors until 1854, when Captain (now Major-General) J. P. Bainbrigge succeeded them, and carried on the publication until 1861, ten volumes of the new octavo series having then appeared.

Captain (now Major-General) C. S. Hutchinson was then appointed editor; in 1872 he issued an index of all papers published from the commencement in 1837, and continued ably to conduct the *Professional Papers* until the close of last year, when volume XXIII.

was published, and another change in the form of these publications occurred.

On the establishment of the Royal Engineer Institute, in 1875, the professional publications of the Corps devolved on its Committee, in accordance with the report of the Committee upon the utilization of the R.E. Institute, which was approved by the Annual Corps Meeting held on the 22nd May, 1875; but a very widely expressed wish for a change in the form of the *Professional Papers*, led, in the first place, to the appointment of a Committee, composed partly of the members of the Corps Libraries and Professional Papers Committee, and partly of members of the Institute Committee, to consider the whole subject of the Corps publications.

This Joint-Committee recommended:—

1. An annual publication, similar in character to the existing *Professional Papers*.

2. *Occasional Papers*, for subjects of pressing interest, translations, memoirs, essays, &c.

3. The *R.E. Journal*, for subjects of social and general, but ephemeral interest.

It should here be stated that, in 1869, a small monthly paper called the *R.E. Journal* was established, giving a list of the officers of the Corps, with their stations and movements, and containing matters of general interest to the Corps. This periodical, it was arranged, that the Institute should take over.

The Joint-Committee had considerable difficulty in coming to a conclusion as to the best size for the publications under heads 1 and 2. On the one hand it was urged that the size of the *Professional Papers*, viz.,—large octavo, was inconveniently large, and that ordinary octavo was a more convenient size. On the other hand, there was no doubt that, for a publication largely illustrated by diagrams, the large octavo had great advantages. On the whole, however, the Committee considered that there was a preponderance of advantages in favour of ordinary octavo.

The Committee of the Institute, probably having in mind the difficulty experienced in carrying on two such similar publications as the old quarto *Professional Papers* and the *Corps Papers*, which

resulted in the discontinuance after a short time of one, came to the conclusion to recommend to the Corps at the Annual Meeting, held on 26th May, 1876, to discontinue the *Professional Papers* as then published, and that the following should be the publications of the R.E. Institute:—

1. *Occasional Papers*, on subjects of scientific interest, to be published quarterly, should there be sufficient matter to justify it.

2. The *Royal Engineer Journal*, to contain subjects of general and social interest as at present, and to be published monthly.

This recommendation was adopted at the Corps Meeting, and during the autumn of 1876 three *Occasional Papers* were published separately in pamphlet form. During this year four pamphlets, each containing four or five papers, have been published, and these are now bound together in the 1st volume of the new series.

The three papers published in 1876 were not printed uniformly nor paged consecutively, and have therefore not been included in the 1st volume, but bound together as an appendix to it.

The change of form in the *Professional Papers* is, it will be seen, principally one of size; and the matter of each volume may be obtained either in pamphlet form, immediately on publication, or bound up, at the end of the year, uniform with the previous volumes of *Professional Papers*.

There is no reason why these *Occasional Papers* should not be made of very great service to the Corps; but for this end the co-operation of every member is necessary; and we trust that during the coming year individual officers, both at home and abroad, and especially in India, will find time to communicate many interesting results of their experiences in carrying on the work upon which they may be employed, or to contribute for the benefit of the Corps at large any useful information which they may have acquired in the course of their various duties.

In concluding this brief *resumé* of the past history of the *Professional Papers*, as an introduction to the new phase upon which they have entered, we cannot do better than quote from the preface of the late Sir William, then Lieutenant, Denison to the 1st volume in 1837.

"The number and variety of the duties upon which we are employed, while they present many obstacles to the attainment of an accurate knowledge of our profession, seem at the same time to point out a system of co-operation as the surest mode of overcoming them.

"If every individual would contribute results of his experience, however trifling, and throw his quota of information into the general stock, he might, in return, draw from that stock rules and examples for his guidance under all circumstances, deduced from the collective experience of his brother officers.

"But, to accumulate this experience, and to make it applicable to the various duties which we have to perform, the talents and industry of numbers must be brought into action, and each individual should avail himself of every opportunity of acquiring information, as well for his own particular benefit, as for that of the Corps at large.

"There is pleasure in the mere exercise of the intellectual faculties, there is pleasure in the acquisition of knowledge for its own sake, but when knowledge is combined with utility, when it is available for the benefit of others, the pleasure is infinitely increased."

ROBERT H. VETCH.
CAPTAIN, R.E.,
Secretary, R.E. Institute.

4th December, 1877.

1878.

Vol. I. No. 1.

ROYAL ENGINEER INSTITUTE.

TRANSLATIONS.

PRUSSIAN HANDBOOK

FOR

GENERAL ENGINEER SERVICE.

PART V.

FIELD FORTIFICATION.

[BERLIN, 1877.]

TRANSLATED BY

CAPTAIN J. GORE BOOTH, R.E.

WITH A PREFACE BY

COLONEL SCHAW, R.E.

[ENTERED AT STATIONERS' HALL.]

Printed for

THE ROYAL ENGINEER INSTITUTE, AT THE S.M.E., CHATHAM.

PREFACE.

THE Prussian *Hand-book for General Engineer Service*, is now undergoing revision, and is coming out in separate parts; of these, the 5th Part (treating of Field Fortification), was the first published, and a copy was sent to England for Colonel Lennox, by a friend in the Prussian service, in January last. Colonel Lennox being in Turkey requested me to look over the book, and, if it seemed interesting, to endeavour to get it translated by an Engineer Officer. On examination, it appeared to contain much that was fresh and valuable, and I accordingly lost no time in searching for a translator. In Captain Gore Booth I was fortunate enough to find a willing and energetic worker, who very quickly produced the translation now circulated to the Corps, with some slight revision, which my previous experience enabled me to make. The translation would have formed one of Colonel Lennox' series had he been in England; but under existing circumstances, he has gladly availed himself of the offer of the R.E. Institute Committee to publish it as one of their *Occasional Papers*.

The book will well repay perusal, but I would draw special attention to the following points:—

Chapter I.—The tools carried with a German army, and the mode of transport.

Chapter II.—Tasks for working parties, and the construction of shelter trenches and gun pits. The patterns of the latter, shown in *Figs.* 8 and 9, have been tried at the Staff College, and were thought to be less convenient than the larger pattern given in Wagner's *Grundriss der Fortifikation*.

The investment battery (*Fig.* 11) is very similar to some of those thrown up by the Germans in the investment of Paris; it has advantages, as regards cover for the gun detachments, over the Austrian battery, which was used at Sadowa, and of which Wagner gives the details in *Plate* III., *Fig.* 18.

Chapter IV. deals with the preparation of existing localities for defence, and contains some valuable hints for the defence of woods, and good examples of defence of farmsteads and villages, with estimates of time and labour, and distribution of the garrison.

Chapter V. describes the formation of artificial strong points in a battle field, either by strengthened shelter trenches, or redoubts. The former expedient is novel, and appears worthy of consideration. The types of redoubts given are also novel, and have some very good points; for instance, the rounded crest, and gentle exterior slope of the parapet, and its careful masking by covering it with the growth on the surrounding surface, the omission of gun emplacements in them, and the provision of splinter proofs. It is, however, doubtful whether the labour bestowed on such works, which, after all, can hardly be expected to withstand a determined attack, might not generally be more profitably employed in other ways; and this is the view taken by the author.

Chapter VI. treats of the different kinds of obstacles. The method described of forming palisading is decidedly inferior to ours; and the stockades are comparatively imperfect, although more complete than many that were made in 1870-71, and which answered their purpose. The wire entanglement (*Fig.* 85—not very clearly indicated) is a most formidable obstacle; its construction involves more labour and material than we have hitherto employed; but the result appears to justify this expenditure.

The paragraphs on abatis are very valuable, and the pattern of "bough abatis," shown in *Figs.* 87 and 88, is very good. It will be noticed that the small excavations slope the reverse way

to the excavations used in our service to hide an abatis from artillery fire.

From Chapter VII., on revetments, we have not much to learn. The clay revetment (plackage), and the water fascine revetment are, however, worthy of notice.

The tables at the end are useful; but they would require modification to suit our system of work.

The word "Engineer" has been used in this translation as the most intelligible English equivalent of the German word *Pionier*.

H. SCHAW,

LIEUT.-COLONEL, R.E.

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ERRATA.

Page 13, line 21, *for* "to one four metres high" *read* "0·40m. to 1 metre high."

Page 21, under heading *a. Front Line*, No. 5, *for* "one man to 3 metres" *read* "one man to 2 metres," and after para. 6, *for* "total men 140," *read* "total men 125."

CHAPTER I.

PRELIMINARY.

§ 1.

THE aim of fortification is to increase the defensive capability of a position.

According as fortification has a permanent or temporary aim, and according to the time available for its execution, as well as the means at disposal, it is distinguished as follows:—

1. Permanent Fortification.
2. Semi-permanent „
3. Field „

The first two kinds, which are carried out during peace time, on the commencement or during the continuance of warlike complications, and which, besides, require considerable materials for their execution, are treated of in the third part of this handbook.

Field fortification has only a temporary object, which depends on the immediate situation of the campaign, and is carried out at the time, and with the means available on the ground.

§ 2.

The kind of works to be thrown up depends essentially on the nature of the ground; in utilizing the latter for defence, the first aim must be to bring one's own fire into play in the most advantageous way, and to cover oneself as much as possible from that of the enemy.

In order to increase the capability of defence of the ground, it can be specially prepared to this end. While, however, the defender is in the position to avail himself, from the first, of these advantages, the assailant is restricted to utilize the cover that may offer, *en passant*, and to place the important points occupied by him in a state of defence, as supports in the event of his further attack failing.

In an open country it is most necessary to supply the cover that is wanting in a way favourable for one's own fire effect. In an enclosed country the cover on the spot must be adapted to the purpose, and any objects that obstruct one's own fire, or give shelter to the enemy, removed or rendered harmless.

Positions are peculiarly favourable for defence by fire-arms when

the field of attack is commanded by direct fire, and also by flanking fire from particular points.

In positions, especially when of great extent, strong points of support are necessary in order to prevent a long line from being utterly lost, should it be pierced at one point, or should a wing, not resting on an obstacle of ground, be overpowered. It may also be necessary to give isolated points, such as posts barring defiles, posts to cover retreat, posts on lines of communications, and so forth, an increased capability of defence, so as to make them strong points of support; as such points of support, natural cover favourably situated such as woods, farmsteadings, villages, &c., should be made use of and prepared to the best advantage. In their absence such points of support are to be made by special means.

Finally, the defensive capability of a position will be increased by the enemy's advance being cramped or rendered difficult by obstacles.

§ 3.

The necessary works in field fortifications, according to the foregoing, may be summed up as follows:—

1. Preparation of slight defensible cover.
2. Arrangement for defence of existing cover.
3. Arrangement of natural cover for tactical points of support (Stützpunkten).
4. Preparation of artificial points of support.
5. Preparation of obstacles.
6. Preparation of the revetments rendered necessary by these works.

The extent to which the foregoing works may be carried out will be decided by the end in view, and the difficulties which the formation of the ground and the local circumstances present to the work, taking into consideration the number of workmen and the available time.

When, with regard to the latter, one cannot reckon on the time being extended, only such works are to be commenced at first, which can be finished quickly.

They must be simple in form, and easily constructed; moreover, they must be so designed that with more time available the position may be strengthened and extended without difficulty. Under this point of view the separate works are described in the following chapters:—

§ 4.

The execution of field fortification falls to the lot of all the troops who take part in the fight. The Engineers (*Pionier Truppe*), from their training, are specially fitted for this, and should, therefore, be employed in the first line. In extended positions they undertake the heavy work, and give the necessary instruction to the other troops.

The most important tools carried with each description of troops are given in the following tables :—

Description of Troops.	Earthwork.			Woodwork.			Remarks.
	Spades.		Picks.	Axes.	Hatchets.	Saws.	
	Large	Small					
1. *Infantry Rifle Battalion*—							
a. Carried by the men.....	—	200	—	—	40	—	
b. On wagons.....	54	—	18	12	27	—	
Total.....	54	200	18	12	67	—	
2. *Cavalry Regiment*—							
a. Carried by the men.....	—	—	—	—	108	—	Utensils and explosives to destroy railways.
b On wagons	8	—	—	—	6	—	
Total.....	8	—	—	—	114	—	
3. *Battery*—							
a. On the guns.....	6	—	6	—	12	—	Tools for armourers and shoeing-smiths.
b. On the other wagons.....	23	—	12	14	24	—	
Total.....	29	—	18	14	36	—	
4. *Pioneer Company*—							Cramps, cordage, nails, tongs, files, hammers (miner's), hammers (carpenter's), push picks, augers, knives. In powder wagons all miners' tools.
a. Carried by the men.....	88	—	44	45	17	—	
b. On entrenching tool and artificers' wagon.....	60	—	30	20	—	12	
Total.....	148	—	74	65	17	12	
5. *Divisional Bridge Train*—							
a. In 3 entrenching tool wagons.....	600	—	150	90	—	30	60 cramps, cordage, tools for carpenters, armourers, shoeing-smiths, and saddlers.
b. Artificers' wagon.....	—	—	—	3	1	3	
c. On the pontoon wagon..	14	—	14	—	14	—	
Total.....	614	—	164	93	15	33	

CHAPTER II.

PREPARATION OF SLIGHT DEFENSIBLE COVER.

§ 5.

WHERE the ground offers no good natural cover, protection for the troops engaged against the enemy's fire must be provided as follows :—

Shelter-trenches for the infantry, gun-pits, and where necessary, limber-pits, for the artillery.

This cover is, as a rule, constructed of earth, as the readiest and best material.

The kind of soil is distinguished as follows :—

1. Easy soil, which can be excavated without difficulty with the spade only.

2. Medium soil, which can be excavated with difficulty, requiring occasionally the use of the pick.

3. Difficult soil, which can only be loosened by the pick. The quantity of earth which an untrained, but diligent workman, can excavate in one hour, singly is :—

In easy soil	... ...	1 to 1·2 cubic metres.
Medium soil	... ...	·75 ,,
Difficult soil	... ...	·40 ,,

The power of excavation is proportionately greater in still shorter time, but is, on the other hand, less for a longer time, so that in four hours work the average amount done in one hour can only be counted on as :—

In light soil	... ...	·7 cubic metres.
Middling soil	... ...	·45 ,,
Heavy soil	... ...	·20 ,,

A. CONSTRUCTION OF SHELTER-TRENCHES.

§ 6.

The principal desideratum for the favourable disposition of shelter-trenches is, that the ground in front should be swept as much as possible.

For this it will suffice, if a shelter-trench is made where a shooting line can be placed during the fight.

Also, similar trenches can be made first for the concealment, and then the delivery, of massed fire for companies and battalions extended in line.

The profile of the shelter-trench must depend on the various firing positions of the men, so as to allow of a quick and easy execution.

The least height required for cover for a man is where he fires lying down; the profile of a shelter-trench, suitable for this, is shown in *Plate* 1, *Fig.* 1. By further improvement it is formed into that shown in *Fig.* 2 for firing kneeling, and in *Fig.* 3 for firing standing.*

The width at bottom of this trench, from one metre up, allows in rear of the soldier firing, the space necessary for the officers and under-officers directing the fire, and admits of the supporting troops coming in to fire in two ranks.

A shelter-trench, as in *Fig.* 1., has this advantage—that the state of the ground, for passing over, is least impaired by it. If this has also to be taken into consideration in the other profiles, then the parapet must be placed back from the edge of the trench, say a foot (·25 metres), so as to be more easily surmounted.

In particular cases it may also be desirable to have a communication, covered from view, in rear of the men firing. For this purpose a shelter-trench of profile, *Fig.* 4, is suitable, which allows, at the same time, the garrison to place themselves under better cover on the steps.

A soldier requires for the convenient handling of his piece at least ·60 metres of front. Telling off the whole length according to his required amount of room, five men to 3 metres of shelter-trench, means a close occupation. Ordinarily five men are reckoned to four metres in length.

§ 7.

In making long shelter-trenches the workmen must be found in small parties (about equal to sections, züge), and these told off to appointed portions.

They are then posted best in the following manner:—

Each party having arrived at the place where they are to work, pile their arms and lay down their packs. If the work is not in the neighbourhood of the enemy, the troops parade in clothing suitable to the work.

* The scale of these figures, where not otherwise stated, is $\frac{1}{100}$.

The entrenching tools, if they cannot be brought up by the troops, are issued from the entrenching tool wagons of the divisional bridge train, which have been brought up to the spot.

In easy soil one spade per man is sufficient; in medium soil, in addition, one pick is required for every four men, and in difficult soil one for every two men.

Each section forms up in single rank on the ground, so that the right-hand man may be on the right of the shelter-trenches to be excavated, and the other men are extended at arms-length apart on the line of the shelter-trench, marked out by pickets or by under-officers.

After the correction of the intervals, and of the alignment of the workmen, which is very necessary, the excavation can be commenced.

In the construction of profile, *Fig.* 1, a continuous trench will be made at the deepest part, and then the flat slope cut away.

In profiles, *Figs.* 2, 3, and 4, the front edge of the trench will first be marked out with a spade, and then the profile will be worked to the rear by portions.

After the earthwork of the parapet is completed, it must be covered with turf, or with anything growing in the neighbourhood; with bushes, snow, &c., in order to make it difficult for the enemy to distinguish, as freshly thrown up earth is visible from a great distance.

This measure will be employed in all earthwork, and will, on this account, not be mentioned again.

If the necessary length of shelter-trench is not reached in one extension of the workmen, they must be extended again in the same way.

The arm's length interval of the workmen amounts to about 1·20 metres. The proportion of workmen to the garrison of the shelter-trench is generally as 2 : 3, and as 1 : 2 when held lightly.

The amount to be excavated by each workman when placed at intervals of 1·20 metres is, in

Profile	1	...	...	...	·27 cubic metres.
„	2	...	...	...	·60 „
„	3	...	...	...	·97 „
„	4	...	...	...	2·10 „

And according to the nature of the soil the work should be performed in

Profile 1	...	...	In 15 to 40 minutes.
„ 2	...	...	In 30 min. to $1\frac{1}{4}$ hours.
„ 3	...	...	In 1 hour to $1\frac{1}{2}$ hours.
„ 4	...	...	In $2\frac{1}{2}$ hours to 5 hours.

The number of workmen and the time for any trench may be calculated accordingly.*

§ 8.

There are many materials available, especially near inhabitated places, which, when used for constructing cover, accelerate the work, especially in stiff soil.

Among these are casks, faggots of brushwood, logs, or billets of wood, and such like.

These are placed or piled up on the alignment of the cover to be made, and covered in front with earth, which is taken from a trench in rear. (*Figs.* 5 *and* 6).

The further employment of such material for defensive cover will be mentioned in the following chapter.

§ 9.

Shelter-trenches, which, from their position, are more or less exposed to enfilade fire, can have special cover provided by means of traverses.

Intervals of 3 to 4 metres wide may be left here and there in the excavation of the shelter-trench, round which the trench may be carried, and the earth formed on the part of the ground remaining (*Fig.* 7.)

Such a careful defilading of a shelter-trench is specially used in investment warfare. In this case, as it becomes generally a defiladed approach, the use of special connecting trenches (communications) is necessary.

These must have a height of cover of at least 1·8 metres, and at the same time to avoid enfilade, they are directed as obliquely as possible, or as in shelter-trenches, provided with traverses.

If the trenches are to be available in wet weather care must be taken to drain off the rain water, and this should be thought of in laying them out.

As a rule, drainage can be provided in steeply sloping ground by means of small trenches to lead the water off; otherwise, deep holes, serving as wells, are to be excavated here and there in the rear slope of the trench.

* For these, as for all other calculation of work, the data will be found in the tables in the appendix.

Care must be taken to have good drainage in all sunken works of fortification mentioned further on, even if the construction of the work is carried out in dry weather.

B. PREPARATION OF COVER FOR ARTILLERY.

1. GUN-PITS.

§ 10.

Cover for artillery used in the field is distinguished from that used in the attack on fortresses. The choice of points for the disposition of cover follows, in the first place, the principles laid down for the employment of artillery.

Existing excavations, shallow dry ditches, heaps of earth, undulations of the surface, hedges, fences, &c., which lighten the work, are to be made use of as much as possible.

The construction of gun emplacements is specially to be avoided in the immediate neighbourhood of woods and localities, or in front of objects, on which, as back ground, the batteries can be easily distinguished, and also on stony ground.

It is to be desired on the other hand that the cover should be hidden from the sight of the enemy, by brushwood, corn, &c., in front. In investment warfare, if such natural masks are not to hand, then artificial masks of brushwood may be placed with advantage, 50 to 100 metres in front of the gun emplacements, of sufficient breadth, and in irregular form.

Shelter-trenches, for the infantry told off to cover the gun, should be laid out on suitable points in advance of and to the flanks of the gun-pits.

§ 11.

The construction of gun emplacements in the field is recommended when it is anticipated that the artillery has to be in action for any length of time.

This can be done best before the battery takes up a position, but can also be undertaken in pauses during the action.

The distance from centre to centre between the gun emplacements should seldom be less than 16 metres (20 paces).

After the position of each piece in the battery, whose front has to adapt itself to the ground, and, therefore, usually is not in a straight line, is decided on, three metres (about four paces) are measured for each gun emplacement in front, and at right angles from each

and three metres (about four paces), to the rear, the front angles cut off for ·80 metre (one pace), and the six angles marked out.

Then follows the excavation of the gun-pit and the formation of the parapet, which is well stamped at intervals, according to plan and profile (*Fig.* 8).

Six to ten men per gun perform the work in one-half to one hour, according to the nature of the soil.

The interior slopes are to be as steep as possible, and in loose earth are to be revetted in form of steps, with sods.

In them, a little above the bottom, holes may be formed (*Figs.* 8 *and* 9) where possible, lined with wood, for the storage of ammunition.

If time allows, trenches on each side, whose bottoms are ·50 metres below the bottom of the gun-pit, should be excavated to give better cover to the men.

§ 12.

Exceptions to the foregoing may be necessary.

a. If the works are constructed on elevations, then, in order to make them as little visible as possible to the enemy, the excavation may be made to the full depth of a man's knee, and the glacis-like "remblais," can be thrown to the front and sides, entirely or partially, and the earth so distributed to the rear that it shows no observable elevation. The disadvantage of this kind of cover is that it takes twice to four times the amount of time to construct.

b. If the works are constructed in a depression, the guns can be placed on the natural surface of the ground, and the cover be made according to *Fig*, 10, where the earth is taken out of a ditch in front. This kind of cover also requires a considerable amount of time for construction.

§ 13.

Gun-pits in investment warfare are, as a general rule, traced in a straight line, secured from enfilade fire, at right angles to the principal line of fire; if, on the contrary, the aim is rather to bring a greater portion of the ground uniformly under fire, the trace can be carried out in the required line, entirely according to the ground.

The gun emplacements, placed ten metres from centre to centre, should be constructed according to *Fig.* 11, *Plate* 2.

The bottom, in soft soil, is to be strengthened with planks or other materials to hand (temporary platform).

The trenches between the emplacements, and on the flanks, afford better cover to the men, and allow of the disposition of projectile and cartridge recesses.

Those on the flanks, when necessary, are lengthened to the rear as communication to the limbers.

The thickness of parapet must be greater (five metres) in front of the gun emplacement than in front of the communication (about three to four metres).

If the line of fire is quite determined on, the parapet can be so much raised to the right and left of each gun, that trough-like gaps are the result.

In the gun emplacement the whole interior slope must be revetted, but in the communication this is only necessary in very loose soil.

In the latter, recesses for ammunition should be constructed at least ·5 metre above the bottom of the trench, of wood material previously prepared (sides and roofs of planks, bottom, and back of boards).

If the troops, in order to be in greater readiness, are obliged to remain any length of time near the guns, special blindages should be built, simplest in the battery itself by covering over the communication trench with railway iron or strong baulks.

§ 14.

The materials necessary for revetting the parapet (hurdles are best), the wood for the ammunition recesses and the platforms, as also the materials for the blindages, should be formed and prepared, if possible, before the construction.

For the work on each gun emplacement eight to twelve men are necessary (four to six men for the gun emplacement, and two to three for the excavation of the adjoining half of the communication, right and left). For one to two gun emplacements one under-officer. Time required for the work, according to the nature of the soil, two to four hours.

The front and centre lines of the gun emplacements are first determined by the officer in charge of the work, and their position marked by pickets.

Each under-officer next marks the angles of the gun emplacements to be constructed by him, as well as the width at bottom of the communication, and causes the edges of the excavation to be lightly traced out.

The earth is distributed over the parapet, and from time to time well stamped down.

In the gun emplacement the loosening of the soil at the bottom by thrusts of the spade is to be avoided as much as possible, so as to keep it very firm.

Lastly follows the marking out and making the slopes as well as ramps, and the revetting the interior slope of the parapet, simultaneously with which the construction of the ammunition recesses, and afterwards possibly the building of blindages, and the communication to the limbers.

2. COVER FOR LIMBERS.

§ 15.

The limbers belonging to the guns must remain near them, so as to lighten the work of supplying the ammunition. They must, if possible, be placed 50 to 100 metres in rear of the guns, covered by the ground, buildings, &c. If the latter is not possible, then it is necessary, especially in investment warfare, to construct special cover for limbers, or to complete imperfect cover, such as banks of earth (erdrandi), trenches, &c.

The height necessary for cover is from 2 to 2·5 metres. If the limbers can be placed to the rear, and to one side of the battery, the most complete cover can be obtained by the excavation of a trench, 75 metres long, in which the limbers stand with the teams, hooked in, one behind the other. Convenient ramps, to allow of their being driven in and out, should be made at the ends of the trench. The rear slope will be cut away at a slope of $\frac{1}{2}$, so that, if necessary, the limbers can simultaneously abandon the trench. (*Fig.* 12).

These trenches require much work. Generally, therefore, one must be satisfied with covering only the limbers, in which case they are placed at right angles to the line of cover.

For each limber a ramp for entrance is excavated, and a trench formed to connect it with the other limbers. (*Fig.* 13).

If the limbers are placed behind the battery (gefechts mässig) ready for action, the communication between the pits are left out, so that the limbering up may be effected in the most direct way between the pits. (*Fig.* 14, *Plate* 3).

CHAPTER III.

ARRANGEMENT FOR DEFENCE OF EXISTING COVER.

§ 16.

In a position chosen for defence, the ground will, as a rule, offer a number of objects affording cover, which, with a little help, can be arranged for defence, and so render unnecessary at those places, the construction of special cover.

In this chapter only the simplest kinds of cover are treated of, viz., the various irregularities of the surface of the ground and fences, while the larger description of natural cover (on the ground), such as woods, buildings, and localities (örtlichkeiten), are discussed specially in the following chapter, as points of support of a defensive position.

A. Preparation of Pits, Trenches, Hollow Ways, and Embankments for Defence.

§ 17.

Pits, trenches, and hollow ways, from whose edges a satisfactory view of the ground in front is possible, are, as a rule, fitted for defence without further preparation.

If they have steep edges and great depth, then it is only needful by the construction of some steps, to facilitate the occupation of the slopes.

To do this thoroughly, the arrangement for defence consists in cutting out a banquette, about one metre wide, and making convenient steps or ramps (*Fig.* 15).

If the view of the ground in front is possible from the edge, the excavated earth is chiefly thrown into the trench in rear, so as to hide the defensive preparations from the front.

If, however, the full view is wanting, then the ground cut out must be formed into a parapet in front of the edge, so as to attain it (*Fig.* 16).

In shallow ditches higher cover can be obtained by deepening the ditch and throwing up a parapet (*Fig.* 17).

In embankments, the side away from the enemy will, as a rule, be prepared for defence, and in the same manner as the edges of ditches (*Fig.* 18).

If the embankments have, however, a considerable height and breadth, and if the strip of ground in front of the embankment be invisible from the rear edge, and cannot be enfiladed from flanking positions, it is better to form a shelter-trench close to the edge of the embankment next the enemy (*Fig.* 19).

B. Preparation of Fences for Defence.

§ 18.

Under the head of fences, the most usual are hedges, palings, railings, and walls.

HEDGES.

High hedges afford a certain amount of protection, as the men placed behind them are hidden from the view of the enemy.

Holes, about the height that a man fires from, are to be cut through, through which a man can fire his piece, and can watch the ground in front satisfactorily.

If cover from rifle fire is required for the defenders, a shelter-trench will be constructed in rear of the hedge, and the latter thoroughly utilized as an obstacle (*Fig.* 20).

If the construction of stronger cover is desired, the parapet will be constructed in front of the hedge, so as to facilitate the firing of the rifle and the observing of the ground in front. (*Fig.* 21).

Hedges on small banks, to one four metres high, with ditches beside them (called knicks), found as fences in many places, are very useful for defence; if necessary, the banks are strengthened, and the ditches deepened.

PALINGS AND RAILINGS.

§ 19.

Wooden palings and railings of all kinds are, as a rule, treated as obstacles, as they cannot give cover in any way.

Supposing they cannot be fired over from places in rear, a shelter-trench is placed immediately behind them (as in *Fig.* 22), so that the fence may be revetted with sods, &c., as far as the thrown up earth reaches.

Materials are found in farm buildings, such as faggots of brushwood, logs, baulks, planks, gates, doors, &c., by making use of which the construction of the cover can be materially hastened.

§ 20.

Board and plank palings serve as good masks to the defenders, and are obstacles to the attacker.

To prepare them for defence, it is first only necessary to cut

loopholes in the boarding, then to strengthen the fence so as to resist rifle fire. This is done quickest by means of boards, planks, &c., if such are to be found in the neighbourhood, otherwise a shelter-trench must be excavated in rear of the fence (as in *Fig.* 22), or earth from the outside thrown up against the fence (*Fig.* 23).

WALLS.

§ 21.

Walls withdraw the defenders from sight, cover them completely from rifle and, when one metre thick, even from artillery fire, but expose them to danger from splinters of stone.

The defender either fires over them or through loopholes; the latter affords the greatest cover, the former is the most advantageous for the delivery of fire.

The following examples explain the various ways in which walls are prepared for defence according to their height.

Walls up to 1·3 metres allow, without any alteration, the use of the rifle. If they are lower than 1·3 metres, a trench can be formed behind the wall so as to give the full firing height (*Fig.* 24).

In order to prevent the enemy from taking advantage of the wall, and to render it more difficult to surmount, it is recommended to make a trench on the outer side (*Fig.* 25).

In walls over 1·3 metres in height a banquette is placed, most conveniently, 1·3 metres below the crest. Banquettes of earth are the most lasting and give this advantage, that the men can prepare and use as cover the thrown up earth after the possible destruction of the wall (*Fig.* 26, *Plate* 4).

Their construction, however, in the case of high walls takes much time. They will be constructed much quicker if tables, forms, chairs, or such materials, are placed against the wall (*Figs.* 27 and 28).

If materials for the construction of banquettes are wanting, and if the strength of the wall, as well as the firmness of the masonry, is small, loopholes will be pierced, the use of which from without is hindered by the construction of a small ditch in front (*Fig.* 29).

If the piercing of the loopholes is very difficult, as in walls built of large stones, it is better to break down the wall to the firing height.

Walls of 2·7 metres in height allow of placing two shooting lines, the lower one firing through loopholes, the upper over the crest of the wall (*Figs.* 30 and 31).

The high scaffolding necessary for this must be constructed very carefully. The best are like those used in building houses, and they require much time and material.

CHAPTER IV.

PREPARATION OF EXISTING COVER FOR DEFENCE AS TACTICIAL POINTS OF SUPPORT.

§ 22.

The descriptions of temporary cover, of which we have spoken in the two preceding chapters, are not in themselves sufficient to give the necessary strength to a defensive position, or to an isolated post. Strong points of support are very necessary, as laid down in the preliminary chapter.

Woods, copses, buildings, and other localities serve this purpose when their position and nature allow a good range of fire, and guarantee good protection from that of the enemy.

A. Points of Support In Fortified Positions.

1. Arrangement of woods for defence.

§ 23.

Woods form strong positions for defence when the favourable position of their edges gives a good range of fire, especially as regards this advantage, that the troops posted in them are hidden from the view of the enemy. On the other hand they have the disadvantage that they hinder the movements of the troops and the superintendence of the fighting in proportion to the density of their cover, and especially if there be thick underwood.

Lofty woods give sure cover from rifle fire, but they are dangerous from the splinters of wood torn off and scattered by the enemy's artillery fire.

The first problem to be solved in arranging a wood for defence, is to hinder the enemy's entrance to it.

The most convenient means for this is an abatis along the edge, behind which the defender takes up his position. The lines of abatis are to be so traced in plan as to give reciprocal defence or to be flanked by projecting parts of the wood. Where the edge of the wood is of great extent, the disposition of the abatis is limited to the projecting points of the wood as being the natural points of attack.

§ 24.

Only in rare cases are sufficient time and workmen available to carry out the tree-abatis in the thorough way, shown in Chapter VI.

As a rule, one must be contented at first with strengthening the edges of the wood in the hope of later improvement.

Thus in lofty woods strong boughs or underwood are cut down and piled in the form of abatis between the foremost trees; in copses or young woods, ten to twenty metres back from the edge of the wood, small trees are felled and forced in between those left standing in the front.

Behind the masks thus formed the riflemen conceal themselves, making use of the largest trees as cover.

If strong trees are wanting, then cover of earth behind the mask of trees must be thrown up, at any rate at the most important points.

The preparation of the cover can be combined with that of the obstacle by piling up, like a parapet, over the butt ends of the branches and small trees laid as abatis, more of the same in the direction of the line of defence, forced in between trees or pickets driven in, and the whole packing consolidated with earth (*Fig.* 32).

Such parapets can also be advantageously used in front of the edge of the wood, where they act as flanks for long straight edges of woods, or as covers for the exits of important roads (*Fig.* 33).

In these cases the parapet can be slightly strengthened with earth which is here more quickly excavated than in the soil in the woods, which is entangled with roots (*Figs.* 34 and 35).

To bar the road, either some trees are thrown crosswise over each other, or a defensible barricade is made of trees heaped upon each other, between which strong boughs are secured as abatis (*Fig.* 36).

§ 25.

The second problem in the preparation of a wood is the improvement of the communications, especially in woods with thick undergrowth.

In the first place, a communication close in rear of the shooting line is necessary, and this is conveniently made at the same time as the edge of the wood is being placed in a state of defence, the trees or undergrowth being dragged towards the edge of the wood to form abatis, masks, and cover.

The roads still required from the different posts of defence to the supports must be specially cut out, as also further back to the reserves, if the existing network of roads is not sufficient. In extensive woods all roads are to be marked out by sign posts.

Lastly, the construction of cover from splinters of shells and wood is to be attempted if possible for the supports, which are placed in

exposed positions, when the woods, as in investment warfare, are to be occupied for any length of time (*Fig.* 37).

§ 26.

To place a wood in a thorough state of defence as a point of support, further measures are necessary which, after the loss of the edge of the wood, facilitate the continuance of the defence in the interior.

Among the most important are the roads leading in the direction of the attack through the wood. These are closed at certain distances by barricades, round which communications for the use of the defenders are carried.

Next, a second line of defence ought to be made by utilizing any existing entrenchments. Such entrenchments are formed by broad roads running parallel to the front, clearings (Schneussen), enclosures (Gestelle), and glades, or by ditches and water courses.

The works necessary to prepare such entrenchments for defence, include the strengthening of the new line in the manner described in § 24. But numerous openings must be left free for the retreat of the troops engaged in front.

2. ARRANGEMENT OF ISOLATED BUILDINGS FOR DEFENCE.

§ 27.

An isolated building, which is to be fitted up as a point of support of a position, must combine with sufficient space inside a solid construction, which affords the needful security especially against the danger of fire. Houses roofed with straw or shingle are therefore of little use, even with massive enclosure walls, unless the inflammable roof is removed.

The position of the building must allow as free a fire as possible to the front and flanks. Such a form in plan is advantageous as allows, at least, of the side of attack being flanked.

The preparation for the defence of a house known to be fitted for it begins, after the removal of all inflammable objects, with the ground floor and with shutting up all entrances. If there are cellars their outer doors must be barricaded also at the same time.

With this aim the doors and gates of the enclosure are first to be closed in the usual way, but the leaves, if they open inwardly, must be barricaded by wedges driven in and securely nailed by cross bars, or by struts placed against them (*Fig.* 38).

Weak doors are strengthened by thick planks nailed on, or barricaded by barrels, sacks, mattresses, furniture, &c., piled up behind them and strutted (*Fig.* 39).

Big doors, as in barns, can be secured against forcible opening by wagons placed against them. If the leaves open outwards, the handles for opening the doors are to be removed, after they are closed; a barricade on the inside can also be made by strong planks being nailed by long spikes, crosswise over the leaves, under the capsills, and above the groundsills, and the points of the nails rivetted outside. The space behind the door, if it opens outwards, may be barricaded by means of barrels, cupboards, chests, &c.; if it is not considered better to have the barricades placed outside, a trench excavated in front of the door, the earth of which is thrown against it, answers this end (*Fig.* 40, *Plate* 5).

Loopholes are cut in the door for direct fire on the space in front of it.

To secure the retreat of the garrison, in extreme emergency, an exit to the rear is so closed as to open easily and quickly from within. If necessary such means of exit must be provided.

§ 28.

Cellar windows, which allow of the entrance of the enemy, are to be securely closed by heavy articles placed against them or by planks nailed across, &c., as they are not as a rule occupied.

The windows of the ground floor are always used for defence. If strong shutters are attached they are closed and provided with loopholes and strengthened by planks nailed across, with mattresses, sods, or dung stuffed between the shutter and window. If there are no shutters then the windows are barricaded by wardrobes, commodes, and other furniture placed in rear, over which the men fire, or, which is better, are nailed up and barricaded with stone, boards, planks, crossed timbers (Kreuzhölzern), mattresses, &c., care being taken to leave loopholes (*Figs.* 41 *and* 42).

If windows are entirely wanting, or not enough to afford a sufficient amount of fire, loopholes must be broken through the wall of the place.

These loopholes, as well as those cut through doors and windows, must be so high (about 2 metres) above the ground outside, or above a trench in front of the wall, that the enemy cannot make use of them from the outside.

It is advisable to form a second line of defence at any rate in rear of the barricade of the principal entrance (*Fig.* 43).

§ 29.

In the upper stories the barricading is not absolutely necessary,

and will be carried out at most to the height of the shoulder above the floor. A considerable fall is given to the soles of the loopholes which are to be broken through, whereby a range over the ground surrounding the building is possible.

If there are projecting bow windows or balconies they are utilized by blinding their parapets, and even by loopholes cut through their flooring so as to keep the foot of the wall under fire.

Much trust is, however, not to be placed in these artificial preparations, as a few well aimed shells quickly destroy them.

On the roof, the dormer-windows are first utilised as loopholes and more are made by taking out slates.

The last thing to be done within the building is the placing in readiness vessels full of water on each story, to enable a fire to be extinguished at once.

In front of a building which is to be placed in a state of defence, the various objects which hinder the defender's fire, and give cover to the enemy are to be removed.

This clearing of the ground in front (see Chapter VI., A.) in the immediate neighbourhood of the building must be taken in hand at the same time as the first disposition for defence. If there are trees or bushes, they should be placed as abatis at the angles of the building, as these places can be only imperfectly held under fire as a rule.

§ 30.

The strength of the garrison of a building depends on the size of the available stories, as well as on the number of openings either existing or to be made.

If one man be reckoned per metre on the enclosure wall, and if a tactical unit of the troops bearing the nearest proportion to it is taken for garrison, it suffices at any rate for a strong defence, and is sufficient also for carrying out very rapidly the most necessary defences and, in a few hours, the entire projected disposition for defence.

3. PREPARATION FOR DEFENCE OF FARMSTEADS, FACTORIES, RAILWAY STATIONS, &c.

§ 31.

As points of support in a defensive position, these may be usefully employed if they allow, from their position on the ground, an extensive and unimpeded range of fire to the front, and possess in their separate parts a certain strength to resist the enemy's fire, and give security against danger of conflagration.

The defensive preparation of a farmstead begins with the removal or destruction of all inflammable objects.

The next thing to be considered is the preparation of a defensible enclosure, and the clearing of the immediate foreground.

The fences enclosing the court-yard and the adjoining enclosure walls of the house are used as advanced lines of defence, while the principal building, usually the dwelling-house, if favourably situated and suitable, is specially fortified as a keep or reduit.

§ 32.

For the stubborn defence of the outer enclosure of the farm one man per metre run is reckoned.

The disposition for defence of this enclosure is carried out as explained in Chapter III. and previously in § 2. The materials supplied by the work of clearing in the immediate foreground are utilized as obstacles.

Any gaps or openings are closed either by barricade-parapets, or by shelter trenches, and these are often arranged projecting forward so as to obtain flank defence.

In fortifying a railway station, the sleepers and rails offer a very suitable material for the rapid closing of gaps, or the extension of the defensible line.

The sleepers or rails are piled between two sleepers sunk in the ground and fastened together with wire (*Fig.* 44), or they are piled up in front of openings and propped up against the standing part of the wall (*Fig.* 45).

§ 33.

A building suitable for a reduit must fulfil the conditions laid down in § 27.

The position of this on the side of the farm unexposed to the attack, favours a uniform range of fire on all parts of the front line, for which purpose as free a field of vision as possible is to be made in the space between.

The fortifying of such a building is carried out as laid down in No. 2 of this Chapter.

Its garrison should be separated from that of the front line, and its commander should be made individually responsible for the defence of his post.

§ 34.

For the number of workmen required to fortify a farm the following example serves as guide.

For the thorough defensive arrangement, in three to four hours, of the farm-house shown in *Fig.* 46, the following labour is requisite.

a. Front Line.	Men.
1. Removal of straw from barn *c* and stables	15
2. Throwing up an earth banquette behind the wall of the courtyard (1·80 metres high) from *e* to the stables, including barricading the gate with casks, 60 metres at 3 metres per man	20
3. Piercing loopholes in the outer walls of the barn and stables, 42 in number, in rubble masonry, one loophole per man per hour	14
4. Excavation of a V shaped ditch in front of the loopholes 60 metres in length, 3 metres per man	20
5. Strengthening the wooden fence from stable to *f*, by excavating a V shaped ditch, and heaping up a parapet in front of it, propping up the fence on the inner side, 60 metres long, one man to 3 metres	30
6. Clearing the ground in front, cutting down the fruit trees in front of the garden and forming them into low abatis before the front of the farm; making openings in the fences in rear	26
Total men	140

b. Reduit (*Fig.* 47).	
1. Barricading eighteen doors and windows of the houses *a* and *b* with furniture and logs of wood found on the spot; preparing for barricading two windows to be used as entrances, twenty openings	20
2. Breaking through twenty-three loopholes in houses *a* and *b*	8
3. Connecting houses *a* and *b* by a barricade of beams found on the spot, which are piled up between two rows of uprights; preparing the barricade of the passages with casks ...	12
4. Preparing the yard gate for closing by means of a wagon; placing water vessels in both houses, cutting down the bushes and trees in the garden, heaping them up as abatis in front of the angle of the reduit	20
Total men	60

In all for *a* and *b* 200 men are necessary, or two-thirds of a workman per metre run of the line of defence to be made.

The tools necessary for the various works correspond with the works to be performed by the different parties.

The garrison of the farm building is to be reckoned according to § 30 and § 32: for the front line 230 men, for the reduit 108 men, in round numbers about $1\frac{2}{3}$ companies of 200 men=333 men, 1 company and 2 zugs.

The garrison can, after supplying the necessary guards, men for cooking, &c., place the farm in a strong state of defence in three to four hours, and even in half the time give to it a great power of resistance.

4. DEFENSIVE ARRANGEMENT OF VILLAGES AND TOWNS.

§ 35.

The defensive power of a village depends on its position on the ground and the nature of its environs, its houses, and farmsteads.

The position must enable the ground in front to be seen and to be brought efficaciously under fire; therefore villages which lie at the foot or on the slope of hills occupied by the enemy, can rarely be successfully defended. The nature of the environs must first be taken into consideration and then the interior.

The environs should be as enclosed as may be possible combined with a favourable arrangement for front defence, should allow also of flanking, and should consist of fences which afford cover and are suitable for defensive arrangement.

A village gains substantially in defensive power if the interior is chiefly of massive construction, and from the grouping of the buildings allows a general view, favours, by broad streets and open spaces, the placing of reserves and formation of lines of retreat, and, lastly, possesses chief buildings suitable as centre points for the interior defence.

§ 36.

The boundary fences, in front and on flanks, are selected as the most advanced shooting line of a village intended as a point of support in a position. The occupation of these need not be equally strong in all parts. The threatened salient angles and the lines flanking them, should be occupied in the strongest, and those parts of the boundary fencing most withdrawn from the attack, in the weakest manner.

On an average one man, reckoned per metre run, gives the approximate number of troops needed for this most advanced line of defences.

The occupation, as before mentioned, need not be equally of this strength; but, at first, a portion of these troops are held back in reserve in order to be able to make the line, against which the chief attack is directed, as strong as possible, later on.

Appointed positions should be assigned for occupation and arrangement to individual companies, the total number of which is fixed according to the foregoing calculations, the separate sections are most advantageously arranged so as to include both sides of the main thoroughfares.

This disposition requires, first: barricading the main roads leading from the outside, and in closing any gaps in the fences.

The roads can be quickly closed by means of loaded wagons driven close together, or by heaping up furniture, house and field implements of all kinds, which at first may only be covered with mattresses and beds as a protection against the enemy's fire.

A kind of barricade capable of defence is constructed by tearing up the paving, heaping up the stones, and covering them with earth (*Fig.* 48), or by collecting together barrels, which are first only filled with earth, and afterwards strengthened with a parapet (*Fig.* 49).

To keep open the communication the barricades are carried across in a broken line, and either placed somewhat retired, by which they can be favourably flanked, or pushed forward in front of the exits of the streets, so as to be used at the same time as flanks to the adjoining line of defence (*Fig.* 50).

The fences are prepared for defence only so far as they are favourably situated for an advantageous range of fire. An extension, if necessary, is effected by making defensive cover as shelter trenches, or by simple barricades as, for example, abatis.

The materials for the latter are furnished, as a rule, by the clearance of the ground in front, which is to be begun at the same time as the construction of the front line.

If a village which is to be placed in a state of defence has no front position for a fighting line, then the front can be extended, as far as necessary, by adding shelter trenches.

If there are in the environs of a village many substantial houses, it is recommended, especially in investments and sieges, when a continuous artillery fire, and that from heavy pieces, is to be counted

on, to lay out a front defensive line with shelter trenches in front of the village, withdrawn from the range of splinters of stone.

The environs of the village must not be occupied until the enemy's infantry advances to close quarters, and when consequently the artillery fire on the village has to cease.

§ 37.

When the environs of a village have been closed on all sides exposed to attack, care must be taken to have as free a communication along the whole front, and as direct a connection between the supports and the shooting line as may be possible, by removing any inner fences which may hinder this.

The former are posted behind the most probable points of attack of the front line, as the principal street, behind houses, walls, &c., so that they may advance quickly to strengthen the shooting line. If necessary, special blindages are to be prepared for them.

If there are in the line of the supports, at junctions of streets, or elsewhere, buildings favourably situated and fitted for defence, which may serve as points of support for the front line if driven in, they are to be fortified and specially occupied.

The streets at these houses are to be strongly barricaded, or should they be required to be used by the defenders, are to be prepared for closing quickly.

§ 38.

The experience of village fighting offers this peculiarity, that the struggle in the interior often sways hither and thither, so that the enemy's breaking through the front line does not always involve the loss of the village, if the reserves are at hand at the right moment.

Such reserves are posted in the interior of the village, with the addition of an outer grand reserve in its rear.

While the latter guard the open gorge of the villages, and at the right time break out on the enemy's flank round the sides of the village; the inner reserves are intended, by pushing forward, to throw back the enemy who may have forced his way in, and if this does not succeed, to hinder his further advance. For this, it is advantageous to have in the interior of the village a main retrenchment or reduit, which will be arranged for defence and occupied by part of the inner reserve.

For such a retrenchment broad streets or water-courses intersecting the village parallel to the defensive line, and which offer behind them a new line suitable for defence, are suitable, while a building

specially suited for defence, as nearly as possible in the centre, as, for example, a castle, factory, or church, is to be used as a principal reduit. The defensive arrangement of the section follows according to that for the outer line. Passages for communication with the outer line are to be left open or made in sufficient numbers and breadth. These gaps are to be barricaded by any materials ready to hand. For the fortification of the principal reduit, the conditions already laid down in § 33 are sufficient.

§ 39.

An example will be given in *Fig.* 51, *Plate* 6, for the further explanation of the fortification of a village.

For the arrangement of the front line, *a b c d e*, the fences of the gardens and farmsteads are utilized, so far as they afford an advantageous shooting line; when this is not the case the gaps are closed by shelter trenches. To extend the zone of defence the mill is brought into the line, and is connected by an abatis dragged thither.

The streets leading from the front line to the interior, where they are not enfiladed from the retrenchment, are barricaded at the crossings; the houses at these barricades are arranged for defence.

In the retrenchment, the work is restricted to putting the whole of the brewery and castle in a defensive state, as well as some fronts of houses adjoining. The church with the walled churchyard forms the principal reduit.

According to § 36 and § 38, the detail of troops required for the occupation of the front line and the reduit, as well as inner reserve, is twelve companies, or three battalions. The garrison of the front line requires at first only four companies, to each of which is assigned a separate section of the line, viz.:—

From *a* to *b*	...1	Company.
„ *b* to *c*	...1	„
„ *c* to *d*	...1	„
„ *d* to *e*	...1	„
Total	... 4	Companies.

Out of the remaining eight companies, two hold the entrenchment and the principal reduit, while six companies form reserves in readiness to re-inforce the garrison on the side attacked, or to advance against the assailants if he has effected an entrance.

Before carrying out extensive works, a reconnaissance is made, as

a rule, of the ground, from which the nature and extent of the fortifications are determined on according to the strength, time, and materials at disposal, the workmen distributed with reference to the various objects, and an estimate made of the necessary tools, &c.

According to the estimate of labour in § 34, sixteen hundred men are necessary to carry out the whole of the fortifying under four hours, in other words about two-thirds of a workman per metre run for the intended defensive line.

Taking into consideration this great number of workmen, and that tools in considerable quantities are necessary, the simultaneous execution of the whole work must be abandoned, and those carried out by degrees, according to their importance. The military situation also often decides on the disposition, *i.e.*, a sudden attack may be expected, in which case, all the workmen would be required on the front lines.

The works noted down in § 36 are therefore to be executed first; then later, sufficient communications are to be provided, and in the last place, the disposition of retrenchments and reduits.

§ 40.

The defensive arrangement of towns, as tactical points of support of a position in the field, must be limited to small towns only.

All the rules given in the previous section for villages, apply to the fortifying of towns.

An entrance into a town is, as a rule, possible only by the streets, on account of the environs being already closed. Without any assistance, an effective barricading of the latter, and the defensive arrangement of projecting parts suitable for flanks, or the construction of such works, generally suffices to secure a stubborn defence to the outer circumference.

Regular lines of streets in the interior often render unnecessary the construction of special communications for the inner reserves, and also give full opportunity for the making of retrenchments by the disposition of barricades.

The market-place with the town-hall or church is, as a rule, conveniently made use of, as principal inner retrenchment, and easily arranged as such.

B. Isolated Points of Support.

§ 41.

The various kinds of existing cover spoken of before under A may be of importance as isolated points of support, and may require

to have their defensive capability increased. If, as garrison for their defence, other troops can be reckoned on, as in the case of outlying pickets, these posts should be placed in a state of defence in the same way as points of support in larger positions. But if the post is left to its own resources, such as, for example, "Etape" positions, and the aid of neighbouring works cannot be counted on against the enemy's attack on the flanks or gorge, the boundary of the locality must be closed on all sides.

There must then be chosen, in the centre, if possible, a point suitable for the construction of a reduit and for the placing of a strong inner reserve, and barricaded communications to this point must be provided from all directions.

CHAPTER V.

CONSTRUCTION OF ARTIFICIAL POINTS OF SUPPORT.

§ 42.

The construction of artificial points of support may be necessary if a part of the position does not offer natural points of support suited for stubborn resistance.

The same favourable qualities for defence, mentioned in Chap. IV., and which already exist in the latter, or may be secured by their arrangement, are to be given by the construction of artificial points of support. As a general rule one or more artificial points of support must be interpolated between natural ones placed far apart. But isolated artificial posts may also be utilized in the defence of small positions (defiles, posts to cover retreat), in which they may frequently form reduits to more extensive works of slight profile.

A. Strengthened Shelter Trench.

§ 43.

Shelter trenches of profile (*Fig.* 52) have a greater capability of defence than that described in § 6, and can be executed in a short time by improving the latter.

The men standing on the surface of the ground have a clear view to the front. In the trench the garrison have a convenient communication secured by the heightened cover.

Opportunities frequently occur so to adapt a defensive disposition of this profile to the ground, for instance, on the edge of a slope, that the enemy's advance to storm it may thereby be rendered more difficult.

Otherwise this must be accomplished either by placing obstacles, or by increasing the fire effect by making supporting lines of defence.

If the plan is not decided by the nature of the ground, it will be advantageous to give it an extended form (as explained with reference to field redoubts, § 48) which allows of a satisfactory frontal fire effect.

At the gorge the extremities of such a defensive post should be suitably connected by a trench for cover (*Fig.* 53), in which the reserves may find shelter from the fire effect.

Finally, increased safety from the long continued artillery fire which must be expected, can be attained in these trenches by covering of the simplest kind; strong baulks, 20 to 25 inches thick, should be laid close to each other, and, after covering the larger interstices with planks or poles, should be overspread with earth thrown up from the rear (*Figs.* 54 and 55).

If it appears necessary to arrange the gorge for defence towards the rear, this wil lbe done similarly to field redoubts (§ 50), but with weaker profile.

§ 44.

Such closed defensive posts may be connected advantageously with the important points by means of long lines of shelter trenches, such as are treated of in investment warfare.

They enable their garrison to hold out against the first shock of the enemy till the supports have advanced up to the adjoining lines (*Fig.* 56).

If such defensive posts are isolated, it is recommended to lay out shelter trenches on their flanks and to their rear, whereby they are more withdrawn from the enemy's attack (*Fig.* 57).

Great stress must be laid on traversing those parts of the defensive disposition exposed to enfiladed or oblique fire. If the ground in rear does not afford any covered approach to the defensive line, trenches of communication must be formed (see § 9).

§ 45.

As regards the quick construction of strengthened shelter trenches, it is advantageous, for the execution of the first portion up to '50m., to place two ranks of workmen who can accomplish the work in two hours.

The further deepening is carried out by one rank of workmen, which relieves the other from time to time.

In this way the whole of the earthwork is accomplished in middling soil in four hours.

Obstacles can be placed, at the same time, by separate workmen, also the wood for the proposed blindages can be procured and prepared, so that their construction, which requires about two hours, can be gone on with immediately after the earthwork is completed.

B. Field Redoubts.

§ 46.

If it is considered that the requisite amount of defence and

resistance cannot be given by the strengthened shelter trenches, described in the foregoing sections, field redoubts should be constructed.

By these are understood, as a rule, earthworks intended only for infantry, which suffice, in the most complete manner, to serve as points of support, and are practicable with the force, time, and material available in the field.

The necessity for their construction occurs only on level or slightly sloping ground.

In a position with steep slopes or sharply defined edges, strengthened shelter trenches are more advantageously employed, as they are more easily adapted to the ground and, consequently, allow of these advantages being utilized in a better way.

1. PROFILE AND PLAN.

§ 47.

The profile is a development of that of a strengthened shelter trench (*Fig.* 52) by the further heightening and strengthening of the parapet.

The elevation gives an increased view over the ground to the men firing, increases, at the same time, the cover in the inner trench against artillery fire, and hides the terreplein of the redoubt, enclosed by the parapet, from without.

The strengthening of the parapet to three metres, together with a flat exterior slope (*Fig.* 58), gives protection against complete demolition by uninterrupted artillery fire from field pieces.

In investment warfare, when the fire of heavier pieces has to be expected, the parapet must be still further strengthened.

The increased amount of earth required to be thrown up to form the higher and thicker parapets, is easiest obtained by enlarging the inner trench and, at the same time, constructing an outer ditch.

The exterior ditch is also to be made deeper than the interior one, so that, if necessary, the latter can be drained into it, a profile, such as that shewn as an example in *Fig.* 58, fulfils these general rules.

This gives a total height of cover of three metres, and protects the garrison in the inner trench against an angle of descent of 15°.

As a flat slope between the banquette and the inner trench removes the latter further from the covering parapet, and so lessens the protection, steps should be made instead of such a flat slope.

These steps can, if the ground is not stiff enough, be slightly strengthened by sods or brushwood with little labour, or, still better, revetted with planks, and can, by these means, be advantageously cut out steeper (§ 104, *Fig.* 102).

The bottom of the inner trench receives a sharp fall to the rear slope for the quick removal of rain water. From here it is led away by flat gutters, if the soil is not so porous that the placing of French drains (casks without bottom sunk in the ground) is not sufficient.

The interior slope gives better cover if two-thirds or three-fourths of its height is carried up steep, and it is rounded off at the top. Special artificial revetting is not necessary; it is sufficient for the support of the parapet if sods or brushwood are laid down, when there are not materials to hand such as barrels, chests, tables, benches, &c., which allow of a slight and solid revetting.

If necessary, the slope is revetted properly later on. (*See Chap.* VII.).

The superior slope falls to the front and runs gradually without any sharp edge in a flat exterior slope, taking the form that newly excavated earth assumes of itself. It is only necessary to smooth any irregularities that impair the range of fire or the strength of the parapet.

In the small irregularities of the surface of the exterior slope are placed whatever natural growth clothes the plane of site, so that the parapet may be rendered as invisible as possible.

The profile of the ditch in front is so regulated, that the necessary earth may be obtained with a convenient throw, and that obstacles may be placed in it (*Figs.* 75, 88, and 89).

The slope exposed to fire is, as a rule, carried on a slope of $\frac{1}{1}$, while the other, even in loose soil, may be made steeper.

If obstacles are not to be employed, an equivalent must be obtained by deepening the ditch in front, and in specially stiff ground, by making both slopes steeper (*Fig.* 59).

A glacis is formed out of the surplus earth, which happens generally, even without the ditch being deepened, as newly excavated earth increases in bulk, and, like the parapet, is covered with the natural clothing of the surrounding surface, whereby the parapet becomes still less distinguishable.

Lastly, if possible, light masks of brushwood are to be brought up so as to hide the outline of the work still more.

§ 48.

The requirements to be fulfilled in the plan of the work—strong frontal fire, support to the adjoining lines by flanking fire, and the closing of the work to form a self-supporting post—are shown in the plans given in *Plates* 7 and 8, *Figs.* 60 and 61.

The lines are designated front, flank, or gorge lines, according as they fire to the front, flank, or gorge.

If the front is carried in a straight line (*Fig.* 60) the work is called a half redoubt (*halb redoute*). If it is broken, then both parts are called faces and the work a lunette. They may be used to flank adjoining defensive lines, or lines of obstacles as shown as an example in § 24, *Fig.* 33.

§ 49.

In order to suit the lines of a field redoubt to the ground, and to be able to bring predetermined portions of the ground under fire, the use of straight lines and a regular form in plan must often be dispensed with. The height of the shooting line is adjusted according to small unevenesses of the ground.

Special considerations of defilade, which must be attended to in the disposition of permanent works, are taken into account as regards field redoubts only so far as to arrange the lines as far as possible so as not to subject them to enfilade fire.

This is in the main already attained by the flat form of the trace adopted.

Finally, the cover must be completed, where necessary, by means of traverses, as in the case of shelter trenches.

§ 50.

The gorge is exposed to the fire of the enemy passing over the parapet to the rear. On this account it is necessary, in order to prepare cover for part of the garrison and reserve, to construct a parados, that is a mound of earth thrown up in the interior of the work, the earth necessary for which, is taken from a trench joining the inner trenches of the flanks (*Fig.* 62, *Plate* 9).

The arrangement of the gorge for defence is not necessary, if the danger of being compromised is obviated by efficient obstacles adjoining on the flanks, or by strong reserves held in readiness, or from the work being situated well to the rear.

If this is not the case, the gorge will be closed by a parapet, if necessary, in connection with obstacles or defensible blindages.

With regard to the earth required for the gorge parapet either the trench of the parados should be enlarged (*Fig.* 60*a*, *Plate* 7 and *Fig.* 63, *Plate* 9), or an exterior ditch excavated, joined to the ditches of the flanks (*Figs.* 60, 61, and 64; *Plates* 7, 8, and 9).

In the closing of the gorge of the half redoubt (*Fig.* 60*a*, *Plate* 7), the defence of the gorge is formed only by the projecting line of parapet.

In the broader part of the trench caused by this, blindages can conveniently be made whose construction is shown in *Fig.* 65, *Plate* 9.

In the closing of the gorge of the lunette (*Fig.* 61*a*, *Plate* 8), the defence is obtained by a line of parapet joined to a blindage in the ditch of the parados.

§ 51.

The construction of such a blindage is carried out easiest in the way shown in *Fig.* 65, *Plate* 9.

The earth slope of the trench of the parados, used as one side of the cover, is in loose soil to be revetted, and the ground-sill, laid at the foot of the gorge parados, to be made secure by pickets against slipping.

For the detached wall, timbers ·15 to ·20 m. thick may be used. It is sufficient to place the uprights, cut square at the ends, on the ground-sill at intervals of 1·50 to 2·0 m. and to ram the surrounding earth; the cap-sill laid on loosely will be held in its place by pieces of plank nailed at the sides or by dogs.

The planking of the wall is then commenced from the bottom, and is carried up so high as to leave a loop-hole between the upper plank and the cap-sill.

The roof should be made of baulks, which are laid close together, or with small intervals, and, if from 0·15 to 0·25 m. square, the space may be from 2 to 4 m. in length.

Occasional roof beams, in order to hold up the wall, are either fastened by dogs to the cap-sills or else secured with cleats.

The joints are covered with poles, planks, or brushwood placed lengthwise, to keep the earth from falling through, or, with greater intervals, with strong planks placed crosswise.

The free side of the blindage should be secured against the thrust by strong props.

Instead of such a blindage, the gorge in rear of the parados may be closed by a stockade (*Fig.* 66).

§ 52.

For the construction of such a blindage, if the trees required have to be felled but planks are to hand, there are necessary 10 to 12 working hours, and per metre run three to four workmen (Engineers), in two reliefs.

In the first relief, the trees will be felled and all the wood-work cut and framed together. In the second relief the timbers will be fixed and covered with earth.

§ 53.

The entrance to the work must be given a position as much secured from destruction as possible, and it must be under the closest fire.

The closing of the entrance will either be only prepared beforehand by materials laid down near it, by which the opening may be quickly closed, or it will be accomplished by fixing gates (barriers). For the first, some small thickly branched trees are suitable, these are laid down sideways in front of the entrance, and can be drawn back to barricade it. They are secured by ropes to one another and to pickets driven in. *(Plate 7, Fig. 60a).*

The second kind of barrier is recommended if doors are to be found in the neighbourhood. They are strengthened by planks nailed on or otherwise fitted up for the purpose.

The door is so placed in a piece of palisading that it can only open inwards *(Plate 9, Figs. 67 and 68).* A cross rail placed on the inside prevents it from being forced in from the outside.

In Chapter VI., under "Barriers," stronger methods of closing are treated of.

2. SIZE AND INTERIOR ARRANGEMENTS.

§ 54.

The size of a redoubt is proportioned to the strength of the garrison.

This must not be taken at less than a company, because this is the smallest tactical unit on which in action devolves an independent duty, and because redoubts with smaller garrisons cannot have much importance as points of support.

The total length of the perimeter of the work, including the gorge, even when open, must allow of the entire garrison being employed in one rank. For this about 0·60 metres per man is necessary.

The redoubts (*Plates* 7 and 8, *Figs.* 60 and 61), require a garrison of one company.

During the fight only the faces and flanks are at first occupied, at the rate of about 1 man per metre, and the rest of the garrison of these lines is held together in separate closed up bodies in the inner trenches till later on, for the necessary reinforcement or filling up of losses.

The crest line of the gorge, which is less exposed to attack, should only be lightly held, as a rule, and from the garrison reckoned for this line is obtained a special inner reserve.

The communications inside the work during the fight will be restricted to the cover in the trenches behind the parapet. It is, therefore, necessary to take care that this trench is always available, provision being made for thorough drainage.

The water collecting at the reverse slope of the trench is best taken away to the extremeties of the flanks, and from thence by small channels, if necessary, through the gorge parapet to the outer ditch. The trench of the gorge parados can be drained to these channels, and also to the end profile (at the entrance).

§ 55.

The cover for the garrison from the profiles alone is only attained in a satisfactory way in the trenches in rear of such lines of the work as cannot be enfiladed by artillery. These are, from the flat form of plan chosen, the front line and the gorge parados.

In rear of the latter, the garrison of the flanks can take position if they are in want of the necessary cover, as well as the garrison of the gorge and reserve.

It is, however, desirable to complete the cover for the flanks by the disposition of traverses (*Plate* 10, *Fig.* 69).

These are given a rounded form with a thickness at top of 2 metres, and a height above the parapet of ·50 metres. The slopes on the enemy's side are made $\frac{1}{1}$, and on the others $\frac{1}{1}$.

If there are in the neighbourhood casks or gabions, the large traverses can be conveniently made steeper, and small intermediate traverses formed as well (*Figs.* 70 and 71).

Such a system of traversing is also required for front lines which are liable to oblique fire.

As already mentioned, the profile gives protection to the inner trench, of 1·8 to 2 metres in height, against projectiles with an angle of descent of 15°. The garrison is thus protected against

shell and rifle fire. It is, as a rule, sufficient cover against the still steeper fall of shrapnell bullets, if the men close up to the covering parapet and sit down on the steps. But cover can here and there be provided by placing light shelter roofs over the steps (*Fig.* 72).

3. CONSTRUCTION OF FIELD REDOUBTS.

§ 56.

The construction of a redoubt cannot be performed by a single disposition of workmen, it must be carried out by task-work with reliefs.

As a rule this proceeds in consecutive reliefs, with four hours duration of work.

If there is not a sufficient strength of workmen disposable for this to be done in one day, the work will at first be carried out as a strengthened shelter trench, and afterwards completed.

The earthwork of a redoubt of profile (*Plate* 6, *Fig.* 58) can be completed in two reliefs of 4 hours, if the greatest possible number of workmen be employed.

The excavation of the trenches in this case is divided into two tasks, corresponding with the two reliefs, and so arranged that each trench is at first excavated perpendicularly at the width of the bottom, and then the slopes formed later on.

According to the width of the task one or two rows of workmen can be posted; the latter only when the width at bottom is at least 2·50 metres, usually also only in the first relief.

When two rows of diggers are employed the men are placed chequer-wise, so that one rank can throw the excavated earth through the gaps in the other.

For this reason, an interval of at least 1·25 metres is necessary, and with untrained workmen an interval of 1·50 metres must be allowed.

If only one rank can be posted, as generally happens, in the second relief, the interval, according to the width of the portion, is to be measured off 1·25 to 1 metre.

The determining of the portion, with regard to width and depth, (see example § 60) is to depend on this, that the quantity of earth to be excavated by each man, may be performed in the given time in the particular kind of soil.

If the plan of the work with the edges of the trenches of the perpendicular excavation of the first relief has been drawn or

marked out on the ground (*Plate* 10, *Fig.* 73), the number of the workmen required for the first relief can be determined from the total length and the width of the trenches.

If, as is usually the case, only half the workmen required for the first relief can be posted to excavate the second smaller task of the trenches, the other half can be employed to form the parapet.

Some workmen may be advantageously placed at the angles, during the first relief, especially in strong profiles, who spread the thrown up earth towards the middle of the line.

§ 57.

The execution of the work takes the following course :—

As a preparatory work after the collection of the necessary tools, the crest lines and the cutting lines of the first task must be marked.

The crest line is picketed out at the angles, and in bent or long lines, at intermediate points, on which the heights are marked by small slabs nailed on, or by cross pieces lashed to them.

This is also done for the traverses, by placing pickets at the four angles of the crest.

Next are traced the cutting lines for the excavation, the widths being set off at right angles to the picketed crest line, and then the trace carried on.

The disposition of the workmen can now be proceeded with. During the work, the boundaries of the completed excavation of the trench are to be further marked out with stakes, and the line of the banquette with pickets driven in, whose tops give the height.

In carrying out the work, the earth should be thrown at least as far as the middle of the parapet so that it need not be moved twice.

If, after the traced out portion has been carried perpendicularly to the depth fixed on, slopes or small steps are to be made, this is done at several places under the special guidance of the superintending officer, so as to give the workmen a clear idea of the way to carry it out.

When all the work of excavation ordered for the first relief is finished, the thrown up earth is finally spread over by the whole of the men, and firmly troden down, by causing the subdivisions in close order to double up and down with short steps.

§ 58.

The second relief of the same strength will be employed as follows :—

In the outer ditch, one rank finishes the excavation, while the other rank forms the parapet and finally covers it over with materials from the surrounding ground.

In the inner trench, one rank finishes the excavation, smoothes the bottom, and, if necessary, strengthens the steps with sods, brushwood, or other revetting material, while the other rank forms the interior slope and the banquette, and, if necessary, revets the former.

In a similar way the excavation of the trench for the gorge parados and the gorge parapet, as well as the trench for the blindages is to be carried out.

The large number of workmen allowed for the second relief ensures the completion of the earthwork, even under difficult circumstances.

§ 59.

As the construction of the blindages can be commenced in the second half of the second relief, endeavours ought to be made to form and prepare the materials for this.

The completion of the small covers in the inner trench is, as a rule, practicable at the close of the second relief, that of the large gorge blindage, as a rule, 2 to 4 hours later.

The obstacles may, in many cases, be finished by special workmen at the conclusion of the second relief.

If this is not possible on account of the difficulty in preparation, or on other grounds, as for example,—when an abatis is to be placed in the ditch, these works will be reserved for a third relief, as well as the construction of the gorge blindage.

§ 60.

For further exemplification of the construction of a redoubt, the following calculation for the number of workmen is given :—

Half Redoubt.

	Disposition of workmen.		Number of workmen.		Work done per man.
	Ranks.	Intervals.	I. Relief.	II. Relief.	
			4 to 5 hours.		
1. Exterior Ditch. *Plate* 10, *Fig.* 1.		Metres.			Cubic Metres.
I. Relief = 3 square metres.					
Excavation, front line=50 m. long	2	*1·25	80	—	1·87.
Flanks and rounding corners 2.39=78 m. long	2	*1·25	124	—	
II. Relief=1·3 square metres.					
Finishing the excavation with half the men, as in I.	1	1·25	—	102	1·62.
Forming the parapet, covering with sods with half the men, as in I.	1	1·11	—	102	
2. Interior Trench. *Plate* 10, *Fig.* 2.					
I. Relief=3 square metres.					
Excavation, front line=46 m. long	2	*1·25	72	—	1·87.
Flanks 2·12=24 m. long	2	*1·25	40	—	
Passage round traverses 2·10=20 m. long ...	2	1·25	16	—	
II. Relief=0·60 square metres.					
Finishing the excavation ... ... Regulating bottom of trench for draining Regulating and, if necessary, revetting steps, with half the men, as in I.	1	1·25	—	64	0·75, besides the regulating of slopes and revetting.
Forming, if necessary, revetting the interior slope and banquette, with half the men, as in I.	—	—	—	64	—
3. Gorge. *Plate* 10, *Figs.* 3, *B*, and *C*.					
a.—Trench of the Gorge parados.					
I. Relief=3 square metres.					
Excavation of the whole length of trench=60 metres long	2	*1·25	96	—	1·87.
II. Relief=0·90 square metres.					
Finishing the excavation, regulating the bottom and steps, and, if necessary, revetting; cutting out a ramp as entrance, with half the workmen, as in I.	1	1·25	—	48	1·10, besides the regulating of slopes and revetting.
Forming and, if necessary, revetting the interior slope of gorge and forming the parados, with half the men, as in I.	—	—	—	48	—
b.— Exterior Ditch.					
I. Relief=1·50 square metres.					
Excavation from the rounding of the ditch of the flanks to the end profile 2·40=80 m. long	1	1·25	64	—	1·87.
II. Relief=1·30 square metres.					
Finishing the excavation, with half the men as in I.	1	1·25	—	32	1·62.
Forming the parapet and covering with sods, &c., with half the men as in I.	—	—	—	32	—
c.—Ditch at end profile.					
I. Relief=1·25 square metres.					
Excavation 2.5=10 m. long	1	1·25	8	—	1·56.
II. Relief=0·62 square metres.					
Finishing the excavation and setting up the necessary revetment of end profile	1	1·25	—	8	0·77, besides the regulating of slopes and revetting.
Total			500	500	

* With unskilled men 1·50.

Total number of workmen required for 1st and 2nd reliefs, = 1,000. The whole perimeter of the crest of the work, including gorge and entrance, amounts to about 180 metres. Hence, there are necessary for the construction of the earthwork five or six men to one metre of the crest.

To this are added the workmen for building the blindages and placing the obstacles.

In most cases 500 men suffice for this.

If, instead of the obstacles, the outer ditch is deepened to 2·25 metres, only 100 men in the third relief are necessary.

Hence the total number of workmen required for constructing a redoubt, stands to the garrison in the proportion of about 6 : 1

§ 61.

This large number of workmen and the extensive preparation required demonstrates that the construction of redoubts should be limited to the case where a strengthening of the ground by this means is absolutely necessary.

If the construction is to be possible in the given time there must be no extraordinary difficulties in the earthwork, or in procuring materials, and the tools must be available in sufficient numbers with a proportionate reserve.

All this is often not to be met with in the field, and accordingly delays in completing the work are frequently to be expected.

On this account the construction of still stronger works of field fortification, especially of redoubts with dispositions for artillery emplacements, must, as a rule, be dispensed with.

In exceptional cases, in which such demands are to be fulfilled, semi-permanent fortifications must be employed.

CHAPTER VI.

OBSTACLES.

§ 62.

OBSTACLES are intended to increase the defensibilities of a fortified position.

They will be considered as follows:—

A. Removal of such objects, as offer cover to the enemy from the defenders fire during his approach.

B. The utilizing and strengthening of existing obstacles in front, and—

C. The disposition of artificial obstacles. In connection with this—

D. The removal of obstacles during the attack on fortified positions.

In field fortification, time and means next to tactical considerations have an overpowering influence in deciding the description of, and extent to which the construction of obstacles is carried out, while in provisional fortification and the arming of fortresses the necessities of the case rather decide this.

A. CLEARING THE GROUND IN FRONT.

§ 63.

The removal of objects found in front of a fortified place, and affording cover to the enemy, is called clearing (rasiren) the fore ground.

Cover on the ground which has been removed, as for example trees, is suitably applied to filling up and rendering impassable depressions affording cover to the enemy.

Weak walls up to 0·6 m. thick, are best demolished by placing the greatest possible number of men to knock them down with picks, axes, iron hammers, and rams (trunks of trees slung by ropes).

Stronger walls are more quickly demolished by mining.

If walls are so situated that they can be enfiladed from a line of the position, their demolition is not necessary, as they form an

obstacle to the movements of the enemy. The same thing applies to railings, hedges, and ditches.

If ditches are so situated that they offer cover to the enemy they must be filled up, or at least must be opened up to the fire from the position by cutting away their near edge.

The demolition of stone buildings is most quickly effected by mining, as pulling them down requires much time and labour; wooden buildings should be burnt down.

B. Employment of Natural Obstacles.

§ 64.

Of the natural obstacles which can be made use of for defence, those formed by water are most serviceable.

They are as follows:—

a. Running streams, if they are sufficiently wide, rapid, or deep, so that the enemy cannot cross them without some means of help; further, if they flow between steep, high, or boggy banks, which render the crossing more difficult.

b. Lakes or ponds, which the enemy must go round, so that he is limited to a certain line of attack.

c. Bogs, morasses, wet meadows, and low ground intersected by water ditches, which of themselves hinder the advance, or are easily made impassable.

Among other natural obstacles are to be mentioned steep banks, declivities, detritus (Felsgeröll), impassable thickets, &c.

C. Disposition of Artificial Obstacles.

§ 65.

If time allows, the defensibility can be increased by artificial obstacles. These must be so placed and formed, that they cannot be destroyed from a distance by the enemy's artillery fire; that they do not hinder the defender's fire; that they afford no cover to the enemy, and compel him to waste time in advancing under the most effective fire from the fortification.

Such obstacles are:—

1. Palisades and fraises.
2. Barriers.
3. Chevaux de frise.
4. Stakes, harrows, planks with nails, wire entanglements.
5. Military pits.

6. Abatis.
7. Fougasses (Fladderminen).
8. Damming of water courses.

§ 66.

In connection with the construction of obstacles, an advanced ditch with glacis in front (*Plate* 10, *Fig.* 74) may be made. On account of the great amount of earthwork this entails it is only made use of in field fortifications, when depression or swells of the ground can be turned to account.

The advanced ditch serves less as an obstacle itself than as a trench to cover obstacles placed there (as palisades, stakes, abatis, wire obstacles) from observation and destruction from a distance.

The height of the front glacis and depth of advanced ditch depend for this reason on the height and width of the obstacle to be placed there.

1. PALISADES.

§ 67.

Pointed palisades are stakes pointed at the end, made of round or split wood, 2·5 to 3·5 metres in length, ·15 to ·30 metres thick, which are fixed in the ground in a row, with ·05 to ·08 metres interval, so that the attacker cannot easily surmount them or throw them down.

They are to be so disposed that they are hidden from the enemy's artillery fire, and that the enemy, while storming, cannot find any sufficient or unseen space in their front so as to demolish them. If they are employed in the ditch of a fieldwork it must be 2 metres deep. (*Fig.* 75).

§ 68.

Such pointed palisades are called "obstacle palisades" (Hinderniss pallisaden), because they present only a passive obstacle.

On the other hand a row of palisades, (as for example in closing the gorge—*Plate* 9, *Fig.* 66), which is also arranged for active defence, is called stockading (vertheidigungs pallisadirung).

If this is by its position entirely hidden from the enemy's artillery fire, it can be constructed as in *Plate* 10, *Figs.* 76 and 77. To give better cover to the men firing, two or three pointed palisades are placed close to one another, and the gaps between the second and third, or between the third and fourth, closed by unpointed "breast

palisades," 2 to 2·50 metres long, whose upper ends reach 1·30 metres above the level on which the men stand to fire (*Fig.* 78).

Stockading is often used to form small flanks abutting on closed lines, or as double closing to entrances. When they form enclosed posts they are called tambours (*Fig.* 79).

§ 69.

The placing of the palisades is begun by the excavation of a trench 1 metre deep, and ·30 metres wide, of which the exterior side is, if possible, to be kept perpendicular.

On the bottom of this, close to the perpendicular exterior side, at intervals of about 10 metres, guiding palisades (Lehrpallisaden) are placed upright, in the proper position and of the right height, and held in this position by two pickets, previously driven in, and then firmly nailed to the palisades.

On the top of the guiding palisades nails are driven in and joined by a tightened cord, which gives the line for the tops of all the other palisades. Then the latter are placed, with correct interval between them, close up to the cord and in the trench, fixed in it by earth or stones, and their height corrected by raising or deepening the bottom of the trench.

As soon as a palisade is placed in position it is lightly secured by a clout nail to a horizontal riband, which is securely nailed to the guiding palisades, with the intention of giving the necessary hold to the palisades placed, until the trench is filled up. As soon as 10 to 12 palisades are placed, two ribands are securely nailed on their inner side ·50 metres above the foot, and, as a rule, the same from the top, so as to prevent single palisades from being prised out; however, in hasty dispositions of palisades in the field, this care is not actually necessary. After this the trench is filled, and the earth well rammed.

Placing palisades is conveniently carried out by parties 8 strong. Such a detachment can in one hour get up 7 to 8 metres of palisading, and 5 to 6 metres of stockading, if the trench necessary is previously excavated.

A double number of workmen can make ready the palisades and ribands belonging to them in the same time, if the trees or timbers are so far prepared that they only require to be divided into lengths, or to be split and pointed.

If, for the supply of the materials, it is necessary to fell trees, it

may be taken that a detachment of 3 to 4 men fell top and lop, in about an hour, two trees of suitable dimensions to supply 5 to 6 pointed, or 12 to 15 breast palisades.

§ 70.

Palisades which are placed in a level or inclined position on the slopes of the ditch in order to prevent the ditch from being jumped into, and the parapet from being surmounted, are called fraises (stürm pfähle). They require to be only 2·25 to 2·50 metres long, and 0·15 metres thick, and are pointed at one end for ·20 metres. They are fixed at 0·05 metres apart.

To secure the fraises, the sill (sturmschwelle) *x*, *Plate* 11, *Fig.* 80), laid at the edge of the slope, serves as a bed, and the riband (sturmlatte) *y* is nailed on the top of the fraises, at their ends.

In laying the fraises the slope must be excavated and then filled in again.

Their fixing takes much time, and their employment is exceptional.

2. BARRIERS.

§ 71.

By barriers are understood strongly framed doors or gates, which generally serve to close the passage through palisaded lines or the entrance to a work. These are only to be employed in field fortifications if serviceable doors or gates cannot be obtained from houses, &c.

They are distinguished as single or double leaved barriers.

For infantry a width of 1·25 metres to 1·5 metres is required; for artillery, 2·5 to 3 metres. In the latter case double leaved barriers are necessary.

§ 72.

In making barriers in the field one must limit oneself to a simple, easy, and quick construction.

Fig. 81 shows one equally suited for a single or double leaved barrier.

The leaves of the gate, consisting of half palisades or strong planks *a a*, held together by cross fillets *b b*, and braces *c c*, are fastened to the gate posts *d d*.

The latter revolve on rounded pivots on a wooden block *e e*, in a hole, made with pieces of wood *f f*, and are held up to the fixed gate-posts, *h h*, by a wire loop, an iron band, or a chain, *g g*, in a groove.

The bar *i* on two short uprights *k k*, serves to close it. The stop (anschlage pfahle) *l*, prevents the opening to the outside.

A two-leaved barrier of this kind is prepared and set up by 10 carpenters in one day.

Fig. 82 shows a method of closing suitable for a single-leaved barrier.

The half palisades or planks *a a*, connected at bottom by the fillet *b*, nailed on, and at top by the half-let-in cross beam *c*, revolve vertically on the pivots *d* of the cross beam *c*. The sockets are cut half way into the pair of palisades *e f*, 1·80 metres above the ground.

Underneath, the ends of the palisade *g* serve as a stop. The loose rail *h*, lies in two notches *k k*, in the two palisades *f f*. When open the falling door rests on a bar *l*, which lies on two uprights *m*, in a notch.

A barrier of this kind is prepared and set up by 4 carpenters in one day.

The most complete way of constructing a two-leaved barrier, like those used in fortresses or provisional fortification, is shown in *Fig.* 83.

3. CHEVAUX DE FRISE.

§ 73.

These consist of a squared beam, called the body, ·30 metres thick, and 4 to 5 metres long, which is so pierced crosswise at intervals of ·30 metres, that squared pickets, pointed at both ends, 2·5 metres long, and ·10 metres thick (called feathers), can be stuck through and fastened in.

The feathers are to be prepared of hard wood, or to be sheathed with iron.

The construction of "chevaux de frise" takes much time. They are chiefly used to prolong palisading, iron railings, &c., in shallow water, so as to extend the obstacle into deep water (1·80 metres), and prevent its being turned. (*Fig.* 84).

The single "chevaux de frise" are fastened to the palisading and to each other by chains, and anchored securely against displacement by the current.

4. STAKES, HARROWS, PLANKS WITH NAILS, WIRE ENTANGLEMENTS.

§ 74.

A stake obstacle (verpfählung) is formed with stakes from ·75 to 1 m. long, which are driven into the ground to about a depth of

·5 m. and are placed so thickly that a man cannot put his foot down between them.

A detatchment of four men can fix, in one hour, three square metres of stakes, 6 to 8 men prepare the necessary stakes (about 120 in number) in the same time.

Harrows with the points upwards are fastened down to the ground by pickets driven in crosswise and secured together by poles. If the teeth (zinken), are too far apart, stakes can be driven in between them.

Planks with nails ·1 to ·15 m. long, driven in, serve as a substitute for harrows.

If wire is available in sufficient quantity, it may be used with advantage to bind together the harrows and planks.

All such obstacles can be covered with a thin layer of small branches, hay, potato plants, and suchlike, so as to hide them from the enemy's view.

They are suitably placed in advanced ditches, on the bottom of the ditches of redoubts, in the intervals between other obstacles, and lastly, in the pointed ditches of stockades.

§ 75.

An excellent obstacle, which also suffers little from the enemy's artillery fire, is formed by stakes bound together with iron wire in different directions, forming a wire net.

In order to render it as difficult as possible to cross, the upper wire must not be less than ·90 m. above the level of the ground, and the interval down to the ground filled up with a web of wire of mesh ·70 m. at biggest, by cross wires entwining in various directions.

On this account, it is convenient to avoid the formation of a regular level flat network by changing the direction of the wire downwards and upwards.

To secure the wires, stakes about 1·7 m. long and ·10 thick are driven in so deep that they stand at different heights from ·80 to 1·2 m., if in the clear.

The distance between the stakes will be on the average about 2 m.

It is convenient to use two kinds of wire, a thickness of $4\frac{1}{2}$ m.m. for the larger meshes, and in particular in the upper layer of wire, a thinner one of 2 m.m. for the closer (engerer), interlacing meshes (verp flechtung).

Strong wires are most conveniently fastened to the stakes by staples, which are formed in the simplest manner out of the strongest kinds of wire. The thin wires are to be fastened to the stakes by twisting them round under each other at their crossing points.

The broader the wire entanglement, the more efficient it is. For a slight obstacle a width of at least 10 metres and upwards is to be given.

This obstacle can be made by unskilled workmen, and can above all be placed by itself on the ground in front, and can be laid out on slopes to increase the difficulty of surmounting them.

§ 76.

In order to determine the number of men suitable in practice to form a wire netting, the following regular disposition for the entwining is recommended.

Between each two rows of stakes are placed two rows of netting crossing each other, one falling and the other rising (*Fig.* 85).

Each of these nets is formed by a number of strong wires crossing each other, which are always carried from the foot of one row to the top of the other, in diagonal direction. Besides in each row of stakes, the tops are connected together by a strong wire. Parallel with this last, are further, in each net, eight thin wires, and finally another thin wire stretched midway between each pair of strong diagonal wires and parallel to them.

The wire entanglement, so formed, is explained by the plan in *Fig.* 85, in which for better illustration the intercrossing nets are represented separately. A party of 12 men prepares in one hour 40 square metres of such an entanglement.

For the adequate advancement of this work, 2 men for driving in the pickets, and six to eight men making the stakes and staples, are also required. As regards material for making extensive entanglements, there is necessary, ·3 stakes, ·6 kilogrammes (4·5 metres run) of strong wire, and ·3 k. (12 m. run) of thin wire for each square metre of entanglement.

5. MILITARY PITS.

§ 77.

Military pits are round holes, which diminish conically towards the bottom, and are placed chequerwise, behind each other in several rows.

As obstacles, to the enemy's approach, they are best placed in stiff ground, in front of salient angles, as well as in the intervals between works. To each pit, an upper diameter of ·60 m. and a lower one of ·30 m. are as a rule given, and ·60 m. depth. The intervals between the pits are ·30 m.

In the bottom of each pit a stake is driven, and afterwards pointed at the top. And the intervals are also filled in with stakes. (*Fig.* 86.)

If military pits are to be of value as obstacles, they must be laid out in as many rows as possible, at least seven, behind each other.

The obstacle receives a material addition of strength, if a wire network is stretched over the pits on several strong pickets. The earth thrown out by excavation, is best formed into a glacis in front of the pits, or distributed in their rear.

To the metre run of this obstacle, about 8 to 10 pits are excavated, a work which can be performed by 4 men in one hour, including the distribution of the soil thrown out.

To prepare and drive in the stakes in the intervals, a double number of workmen is necessary.

6. ABATIS.

§ 78.

Felled trees with thick tops, or strong boughs so connected together and to the ground, that the enemy's passing through is made difficult, form an abatis.

According to the materials, they are distinguished as tree abatis (Baumverhaue), and bough abatis (astverhaue).

If the tree abatis is made where the trees are grown, it is called a fixed (hangenden) or natural abatis entanglement, otherwise it is called a dragged (geschleppter) abatis.

In forming a tree abatis, felled trees are laid across or close to one another, with the tops turned to the enemy, in two to six rows, so that the tops of the rear rows cover the butts of the front ones.

In front of a fortification, the trees would give cover to the enemy's riflemen; tree abatis is preferably employed to barricade hollow roads and existing depressions, which already afford cover to the enemy; further to close the intervals between fortifications, and finally, extensively in preparing the edge of a wood for defence.

§ 79.

Tree abatis receives as great a width as possible, about from 40

to 60 metres. The front and rear rows of trees to be felled are marked out by blazing.

If there are single trees standing in front of the abatis, they will first be felled close above the ground, and if possible, dragged by horses by means of chains slung round the stems, to any parts of the abatis ground where the trees are less thick.

Then is commenced from front to rear, the felling of the remaining trees, in such a way that they are made to fall with their tops towards the enemy, with part of the trunk adhering to the stump.

In a dragged (geschleppter) abatis, the trees are completely severed from their stumps; besides the stems are shortened before they are moved to lighten the labour, and they are at the same time cleared of small branches and the bigger boughs pointed.

In order to make tree-abatis quickly, one man per metre run is reckoned, whereby, under ordinary circumstances, the construction is possible in a few hours.

§ 80.

If a bough-abatis is to be brought up as an obstacle in front of a fortification, only the smaller trees and boughs, ·08 to ·10 metres thick, are taken, they are cleared of their thin branches, their stronger ones are pointed, and they are sunk in the earth behind each other in several rows. Such a horizontal (liegender) abatis must be completely seen from the work in rear, and, therefore, it should not stand higher than about 1 metre above the surface of the ground.

To help this, small pointed trenches, from about ·5 metres deep, and 1·5 to 2 metres wide, are excavated (*Fig.* 87), in which the single stems are left overlapping, and are secured firmly with pegs or crossed pickets.

To the latter end ribands or poles are advantageously laid over the boughs, which, when pegged down, hold several boughs at the same time (*Fig.* 88).

In the ditches of redoubts the abatis is either laid in a similar way on gentle slopes, or sunk into the bottom of the ditch behind steep slopes, and besides secured by the previously described pegging, helped by poles or ribands stretched across, and by the earth in the ditch being well rammed (*Fig.* 89).

To distinguish the latter abatis from horizontal (liegender) abatis it is called standing (stehender) abatis.

Both kinds of these abatis receive an essential addition of strength if the boughs are intertwined with wire.

§ 81.

The construction of bough (ast) abatis is carried out successively commencing in this way:—One party excavates the trench and throws the earth on to the inner edge; following this, another detachment lays the boughs, and then fills in the trench again.

If the laying down of the abatis is advanced to a certain amount in the outer row, then the work in the second row may be commenced, and so on.

A detachment to place boughs or trees prepared for laying down may be conveniently 6 to 8 men strong. This lays, pegs, and covers a row of bough abatis, from 8 to 10 metres long, in one hour.

To excavate the trench and to prepare the stakes and poles in the same time, two detachments of about the same strength are necessary.

If the materials can be obtained near the place where they are to be used, the nccessary boughs can be cut, pointed, and brought up by the same total number of workmen, before mentioned, in the same time.

7. FOUGASSES.

§ 82.

Charges of powder which are buried in the ground in front of fortifications and exploded at the moment when the enemy's storming columns cross the spots where they are laid, are called fougasses (Fladderminen).

They are placed in those places which it is anticipated that the enemy will cross in the attack, for this reason especially in front of the salient angles of fortifications, at a distance of 20 to 40 metres.

Instead of fougasses, so-called land torpedoes can be employed. These are casks with charges of powder sunk in the earth, and furnished with fuzes, which, when trodden on, ignite the charge.

8. STOPPAGE OF WATER COURSES.

§ 83.

Water can be employed in three ways as a near obstacle.

a. For forming a marsh, when low lying ground is made impassable by turning on water or by stopping back water courses.

b. As a dam, when flowing water is so swollen by a weir that it cannot be waded through.

c. As a flood or inundation, where a stream is made to overflow and fill up the lower part of a valley by a dam thrown across it.

Marshes can consequently be employed in flat ground and boggy soil, dams with river banks from 2 metres high, inundation with low banks and a rather narrow valley.

a. Forming a Marsh.

§ 84

Forming a low lying piece of land into a marsh by turning on water can be accomplished if, in its neighbourhood, there is available a stream, river, or pond with plenty of water, lying at a higher level than it, from which the water can be diverted by a ditch.

The construction of the water course (zuleitungsgraben) begins at the lowest part, and a measured water profile is given to it.

If the low ground is itself crossed by a ditch which has even a narrow outflow, the ditch is filled up at a suitable place.

In order to give the necessary hold to the thrown up earth, either big stones are thrown into the water courses, between which the earth settles firmly, or a wall is formed by stakes driven in and planks behind them, which prevents the ground being washed away.

b. Dams.

§ 85.

To raise the water level in a flowing stream, a dam (staudamm) is necessary, which reaches from one bank to the other, and which must be so situated that it cannot be destroyed by the enemy. Where time fails a stoppage can often be made at a bridge by trees, timbers, wagons laden with stones, &c., placed across, in front of the supports or piers of the bridge, and a dam thereby formed with branches, fascines, or faggots of brushwood placed in front, and then dung, sods, clay, or fat earth, and so on, thrown in on the up stream side.

§ 86.

The height of the dam must correspond with the depth intended to be given to the water. A depth of 1·8 metres, the so-called military depth of water (militairische wassertiefe), is to be desired. Should this be required at a point situated some distance up stream, then the dam must be raised so high as to allow for the fall from that point to the dam.

The time to carry out the drain and to complete the embankment depends on the velocity of the current and the cross section of the water course.

c. Inundations.

§ 87.

To form an inundation, the margins of the valley in which a river or brook flows, must be connected by a barrier carried across through the water course, which usually must be a dam.

Even if one can utilize for its construction portions already to hand, such as road embankments, railway embankments, and such like, still the earthwork connected with it is in most cases so heavy that one can seldom carry out this obstacle in field fortification.

The crest of this dam must be at least 0·5 metres above the level of the inundation; the width at top about 1 to 2 metres; the slope on the up stream side at least $\frac{1}{2}$; that on the down stream side $\frac{1}{1}$.

In long reaches of inundation, and where the fall of the stream is considerable, the dam to be constructed would, on the one hand, have to be very large, and on the other hand the depth of water would exceed considerably the necessary depth, 1·8 metres, and the construction would require much time.

In such cases it is preferable to construct two or more dams, and consequently several basins (staubecken).

Care must be taken for the defence of this increased number of crossings.

§ 88.

In order to prevent the constantly running water from rising to the crest, overflowing and thus damaging it, a so-called overflow is placed beside the dam, over which the water flows after it has reached the intended height.

The overflow channel (abflussgraben) must be placed so far from the dam that damage to the latter from the current is not to be feared.

Instead of this, in some cases culvert drains are carried through the body of the dam, which may be made of suitable drain pipes.

§ 89.

An inundation forms a good obstacle even with a small amount of depth, if, on both sides of the stream, irregularly placed trenches are excavated from two to three metres wide, and so deep that

where they occur, the military water depth may be obtained after the construction of the dam.

D. Removal of Obstacles during the attack on Fortified Positions.

§ 90.

The removal of obstacles, during the attack on fortified positions falls on the Engineers.

The nature of the obstacles must be determined by reconnaisances, in order that the suitable materials and tools may be prepared before hand, and held in readiness.

The work is carried out either shortly before the attack or in connection with it.

In the first case, the Engineers try to attain the objects to be destroyed, and to execute the work with the materials and tools prepared beforehand, covered by as noisy and sudden a fire as possible from a small infantry detatchment, generally profiting by darkness, so that the defenders alarmed by it have no time to hinder them.

In the other case, the Engineers follow the advance of the attackers with the materials, &c., close in rear of the shooting line.

While the latter, having arrived at the obstacles, lie down and keep up a continual quick fire (Schnellfeuer), the former begin the work.

The result will depend essentially on how far the attackers are able to keep under the fire of the defenders.

§ 91.

In order to surmount pallisading and barriers, against which artillery fire cannot be brought to bear from a distance, materials for filling up (Füllungs-material) are employed, such as sacks of hay, fascines, gabions, by help of which, these obstacles are surmounted.

If they have been already injured by artillery, the gaps are used to make practicable openings by means of hatchets, axes, and saws.

This work is usually, however, a lengthy one, especially so the uprooting or pulling down pallisades with levers or ropes in heavy ground, for which a partial removal of the earth with spades is generally necessary.

The best way to form an opening in palisade gates and barriers is by mining.

§ 92

Harrows and planks with nails must be separated from each other by axes or mauls, and then dragged one on top of another. Stakes

are either cut or broken down, or made passable by hurdles, brushwood or sacks of hay laid on them.

The latter serve at the same time as good cover to the workmen at close quarters.

Wire entanglements are destroyed by cutting through or drawing out the stakes, or by breaking them down.

If the upper network forms a nearly level surface, and if it is made of strong wire, then the net is covered with planks or hurdles for crossing over.

A solid wire netting, constructed according to § 76, may be removed more quickly if the top wire be cut through with wire pincers, or chopped through by hatchets on hammers held underneath.

Military pits are, in easy soil, filled in with spades and stamped round the stakes. If the soil is heavy the pits are filled with sacks, or covered over with planks and hurdles after the stakes sticking up have been cut down.

In abatis there are usually found places thinner than the rest, and where passages can be formed by cutting away the impeding branches.

Dragged (geschleppte) and bough (ast) abatis can generally be dragged on top of each other with ropes by the united strength of several workmen after their fastenings have been loosened.

A suitable passage can also be formed by firing small charges of explosives brought up to the abatis.

§ 93.

Fougasses must be rendered useless, if possible, by destroying the means of firing them (Leitung) if they cannot be avoided after their position has been found out.

The stoppage of water courses can only be removed by the destruction or opening of their barriers.

This is often attained in small dams by artillery fire ; in larger dams it is necessary to have recourse to excavation or mining.

Marshy places can frequently only be passed on planks or hurdles.

CHAPTER VII.

REVETMENTS.

§ 94.

A SLOPE which is to be carried up steeper than the natural slope of the soil must be revetted. Revetments are employed in many Engineer works.

Their execution is, therefore, more fully treated of than their importance in field fortification deserves.

For the correct carrying out of the revetment it is necessary to mark out with laths the direction and the inclination of the slope which is to be set up.

Such indicating profiles are first set up at the ends of the slopes to be revetted, between which there are then more profiles set up at intervals, at about 5 metres, and fixed in line with the first.

A tracing line stretched on the laths, shewing the slopes, allows of the execution of the slopes with symmetrical form.

In a redoubt, for example, the laths showing the slopes for the careful revetment of the steeper slopes of the traverses, of the lower part of the interior slopes, of the slope of the banquette and the end profile, are to be set up as shown in *Plate* 12., *Fig.* 90.

If the exterior forms of the earthen masses have already been determined by profiles, as, for example, in semi-permanent fortification, it is only necessary as regards their revetment to increase the number of profiles by setting up suitable intermediate ones.

Earth, sods, brushwood, and wood serve as materials for revetments.

A. EARTH.

§ 95.

A revetment made with earth is called "Plackage."

In slopes which are intended to stand for only a short time, earth roughly mixed with straw, &c., (wilde plackage,) is used.

This is formed as follows:—

The earth of the slope to be revetted is thoroughly mixed, watered, and firmly rammed with a beetle in layers ·40 to ·60 metres wide,

and ·3 metres high, sloping inwardly, and brought up to a line stretched between the profiles.

Steep slopes of about ¼ can only be revetted in this way if the earth be heavy and stiff.

If the fat earth has to be first brought from other places, the slope to be revetted is previously dug away, and as the revetment is formed the earth is carefully filled in again behind it.

If earth suitable for revetting is not to be got, then straw, twigs, roots, pieces of sods, or whatever else is to hand, can be laid as a binding material between the several layers.

A party of 4 men can revet with earth, in one hour, 6 to 10 square metres of slope, according to the nature of the soil.

In slopes which are intended for longer duration, and which are executed as a rule with all care, the layers are made only ·10 to ·15 metres high, and in order to form turf later on, couch grass is laid on or grass seed sown.

This kind is called regular (Regelmässige) "Plackage."

B. Sods.

§ 96.

The sods most suitable for revetments are obtained from fat or damp meadows.

That dug up from dry soil roots too deep, as a rule, and crumbles in consequence.

They are distinguished as building sods (Kopfrasen), ·30 metre long, ·15 wide, and surface sods (Deckrasen), ·30 metre square, both ·10 metre thick.

The former are laid with the grass downwards, and with their lengths at right angles to the slope, in layers over each other, almost horizontal, but a little inclined inwardly; the latter are laid with the grass outwards, flat on the slope, and fixed to it by two wooden sod nails (Rasennägel), ·25 to ·30 metre long, driven in at the opposite corners. (*Fig.* 91).

Building and surface sods must both be laid "bonded." To lay and fasten the sods, sod mallets (Rasenhammers) are required.

If the whole slope is revetted with building sods, the angles projecting on the face of the slope like steps are struck off with a scarping spade (skarpirspaten), and the slope is well beaten with the beetle (wallschlägel).

If angles occur with this revetment, it is advantageous to prepare

sods of ·30 metres square, so as to form a good bond at the corner (*Fig.* 92).

For revetting with surface sods the slope must be formed less steep, and must be already complete. It gains in strength after a long time by the roots of the sods forcing themselves in, but it protects the slope at once from being washed away by rain.

If the material for the revetment lies conveniently to hand a detachment of 4 men can place, in one hour, 2·5 square metres of headers, and 10 square metres of stretchers as revetment (200 and 110 sods).

§ 97.

For cutting the sods on the ground a right angle is set off, whose sides are marked by a cut ·10 metre perpendicular depth, with a sharp edged spade.

Then the tracing line is stretched out parallel to one side, at the width of the sod which is to be cut (·15 or ·3 metre), and a second cut made, by which strips of suitable width are obtained.

The single sods are then cut off by eye from these, dug up by means of spades, and laid by the side in readiness.

A party of four men can in this way cut in one hour 200 to 300 sods.

§ 98.

When there is a great demand the work of cutting the sods can be considerably aided by the construction of "sod cutters" and "sod lifters," usually not to hand in the field.

The former, a sharp knife pointed at the bottom, is fastened by a socket to a wooden handle (*Fig.* 93). At the socket there is a loop with a cord. The knife is stuck to the necessary depth in the ground, and drawn along the tracing line by a second man by means of a cord; in this way the first man looks after the pressing in of the plough, and takes care that the knife keeps in the direction showing by the tracing line.

In this way the strips of sods are first cut, and a width of ·15 metre to ·3 metre; then the second cut necessary for separating the single sods is made at right angles, also, with the sod cutter.

The sod lifter is a spade with a big, sharp edged blade, which is fastened to the handle at an angle of about 150°, and serves to lift the sods (*Fig.* 94).

C. Brushwood.

1. Wattling.

§ 99.

The simplest way of using brushwood for revetting consists in its being wattled in and out of pickets driven in in the line of the slope. In this way a thick wall may be handily formed which resists the thrust of the earth. This kind of revetment goes on quickly, can be commenced simultaneously with the construction of a parapet, and can be prepared beforehand without detriment to its firmness.

The interval between the pickets is from ·30 to ·50 metre; their thickness ·04 to ·05 metre. Their tops are joined together by a lath. Then the ranging is carried on with a simple wattling, alternately before and behind the pickets, and the brushwood driven down with mauls.

The upper part of the wattling is finished off in a similar way to sap gabions; the visible surface is trimmed off.

When the wattling is carried up to $\frac{2}{3}$ of its height, anchors of withes (wiedenanker) from 1 to 1·5 metres long, are placed 1·5 to 2 metres from each other, carried with a loop over the pickets of the wattling, and laid in the parapet at right angles to the face of the slope. Through the other loops of the anchors, pickets are driven into the parapet which are notched to give a good hold of the anchor loop.

A party of 4 men place in one hour 3 metres run of this wattling about 1 metre high.

Six men cut, prepare, and bring up in the same time, from a distance of 100 to 200 metres, the necessary materials ($1\frac{1}{4}$ bundles brushwood, 2 to 3 pickets, and $\frac{1}{2}$ to $\frac{3}{4}$ of an anchor, per metre run).

Instead of wattling the pickets when pressed for time, a loose packing of leafy brushwood may simply be laid in behind the pickets (*Fig* 95).

The anchoring is then carried out by a lath which is fastened to the picket about $\frac{3}{5}$ of the way up.

2. Hurdles.

§ 100.

Revetting with made hurdles is only suitably employed, as a rule, in siege works, where slopes that have become damaged must be quickly repaired.

The hurdles are placed in line with the slope close to each other, their points downwards, and the pickets driven into the ground.

The end pickets of two hurdles touching each other are looped together, about $\frac{2}{3}$ of their height up, by a long anchor withe, pushed through and secured by an anchoring picket passing through the end loops.

Besides this, each hurdle is provided, as a rule, with two other anchors, which are pushed through the wattling about $\frac{2}{3}$ of the way up, and are held in front by a cross-bar shoved through the front loops, and are securely fastened behind by driving in anchoring pickets (*Fig.* 96).

A party of 4 men revet, in one hour, four to six metres of a sap or parapet, with hurdles (2 to 3 in number).

3. GABIONS.

§ 101.

Revetting with gabions as well as revetting with fascines, to be described further on, is principally employed in siege works and in arming fortresses, where these materials are previously prepared in large quantities.

Gabions are used in the following way for revetting :—

After the necessary room has been made in the parapet or other thrown up earth, single gabions are placed with their points downwards ; they first receive a shove in such a manner that the line of the gabions follows the parapet or earth heap ; then pointed pickets are driven through the wattling into the earth, and about every third gabion is anchored in the same way as that described with regard to hurdles.

Then the gabion is filled with earth and rammed as tightly as possible.

A party of 4 men, in one hour, place 5 metres run of this revetment (8 gabions).

In building traverses, which are revetted on both sides with gabions, the anchoring is carried right through the whole thickness of earth from one gabion wall to the other, so that they mutually support each other. The anchor-withes must on this account receive the necessary length and strength (*Fig.* 97).

When it is necessary to place several rows of gabions above one another, the upper are pushed back to $\frac{1}{3}$ of their width.

The upper row of gabions are conveniently topped with fascines to hold up the earth better.

Casks and tubs are used in a similar way for revetting.

4. FASCINES.

§ 102.

In revetting, fascines are laid longitudinally over each other; those of the lower layer, called ground fascines (Grundfaschinen), are, as a rule, to be sunk to half their thickness in order to give greater firmness to the whole wall.

The ties of the gads of the fascines, must be turned to the interior of the parapet, the ends of the fascines of each layer thrown close together, the various layers under each other in bond, and so laid that the binding withes (Bänder) may lie as much as possible, close over each other, whereby they are not forced out by the fascine pickets being driven in.

When a fascine is correctly laid, it is securely fastened to the ground, or the fascine below, by three fascine pickets, which are driven in at an interval of about one metre between two gads, so deep that the head only projects ·02 to ·04 metre.

After placing, each layer is filled in behind, the new layer placed on the top, and each even layer, on account of the bond, begun with a half fascine.

Every third row should be anchored, to effect which a fascine may be conveniently laid parallel to the revetment (anker faschine) (*Fig.* 100).

Where slopes form an angle, the heads of the fascines should be laid crosswise alternately, as is shown in *Fig.* 98 in the revetment of an end profile. From the figure it is also evident, that in slopes whose base and superior crest do not run parallel, the latter must be the one to determine the position of the layers.

Fascines are frequently employed for making steps.

These are formed, according to their height, of one or two fascines (*Figs.* 99 and 100), the upper fascine is placed back 0·05 metre.

A party for revetting with fascines is conveniently 8 men in strength. They lay, in one hour, 30 metres run of fascines.

§ 103.

A special kind of fascine or brushwood revetting, called (Rauhwehren), is employed for slopes, which must be protected from the action of water.

These revetments must commence one metre above the highest water level, and must reach ·5 metre below the lowest water level.

After the slope has been adjusted to an angle, which should be at least the natural one of the soil, step-like cuts are made in it commencing from above (*Fig.* 101).

On these, water fascines or brushwood ones are fixed with their stems downwards, and their upper open ends spread evenly on the slope (two fascines to the metre run).

Over these so-called spread layers (spreitlage) two or three 18 to 20 feet fascines (würste) are laid, with about 0·3 metres interval, and firmly pegged in with pickets 1·3 to 1·5 metres long. Hooked pickets (Hakenpfählen) are the best.

If the slopes are very flat, about a slope of $\frac{1}{3}$, it is only necessary to cut a step for the lower spread layer (spreitlage).

The earth from these steps is spread over the fascines after they are laid.

D. Wood.

§ 104.

Wood revetting is only employed in very steep slopes, which are not exposed to direct fire, and if the material can be easily procured.

Pickets 1 to 1·5 metres apart, and about ·1 metre thick are either driven or sunk in the line of the slope in the required direction, ·5 to 1 metres deep, and behind them are placed planks or scantlings (Langhölzer).

The pickets must be anchored at about $\frac{2}{3}$ of their height up. The break of the joints of the revetment can be easily made behind the pickets, as where this is not possible, a piece of plank is laid behind the joint. If time allows, the boards, planks, or scantlings are fastened to the pickets by wooden or iron nails.

This kind of revetment is very suitable for retaining the interior slopes of blindages, and of redoubts, which have to be made as steep as possible on account of cover (*Fig.* 102).

The labour and time for the execution of this revetment to be calculated the same as for fascines.

APPENDIX.

TABLES for calculating the requisite amount of material and labour for works occurring in Field Fortification.

TABLE I.

Preparation of Materials.

Materials.	Working Hours.
To fell and top 1 tree ·25 metre thick	2
To prepare 1 palisade from round timber	1
To prepare and frame 1 metre run of uprights, ground and capsills, for blindages	1
To prepare 4 to 5 metre run of splinter proof timbers (Deckbalken) for the above	1
To make 10 to 15 pickets	1
25 Sod pegs (Rasenhägel)	1
To cut 1 bundle of brushwood	1
To prepare 6 anchoring withes (wiedenanker)	1
To twist 12 withes as gads, (Bindewieden)	1
To cut 40 surface sods (Deckrasen)	1
50 Building sods (Kopfrasen)	1

TABLE II.

Consumption of Brushwood.

Required for.	Metre Materials.	To prepare the material.	Manufacture of material.	Total.
		Working Hours.		
1 Fascine, 3·8 metre long, ·25 metre thick	4 bundles brushwood, 10 withes as gads	5	5	10
1 Gabion, 1·25 metre high; ·6 metre wide	2 bundles brushwood, 7 pickets ...	3	10	13
1 Hurdle, 1·3 metre high: 2 metre long	2 bundles brushwood, 7 pickets ...	3	8	11

TABLE III.

Disposition of Earthworks and arrangement of cover on the ground for defence (in reliefs of 4 to 6 hours in middling soil.)

Required for	Working Hours.
1.—Per metre run preparing a line of defence—	
Shelter trenches, as in *Fig.* 1.	½*
,, ,, ,, 2	1*
,, ,, ,, 3	1½*
,, ,, ,, 4	4
,, ,, ,, 52	6
Redoubts (including gorge) exclusive of blindage (hohlbauten)	20 to 25
Blindage in gorge as in profile, (*Fig.* 65)—	
a. Preparing and forming materials	15 to 20
b. Setting up and covering the blindage	20
Blindage in inner trench as in profile, (*Fig.* 72)—	
a. Preparing and forming material	5 to 10
b. Setting up the blindage	5
Defensive arrangement of a House	2
,, ,, Farm Buildings	3
,, ,, Village	4
2.—For a Gun—	
Gunpit (Field Fortification)	6
,, Investment warfare (Cernirungskrieg)	30

* If one extension of the available workmen at intervals of arm's length be sufficient for the whole length of trench to be executed, the time required for the work is lessened by about one-third.

TABLE IV. *Disposition of Obstacles.*

Required per metre run.	Material.	To prepare the material.	For execution.	Total.
		Working hours.		
Obstacle palisading (hinderniss pallisadirung)	3·5 pointed palisades 2 m. run ribands 7 trenails	4 to 8	2	6 to 10
Stockading (vertheidigungs pallisadirung)	3 pointed palisades 2 breast palisades 2 m. run ribands 6 wood or iron rails	5 to 10	2½	8 to 12
Obstacle pickets, 5 m. wide=5 square metres	200 pickets	18	7	25
Military pits, in 7 rows, with pickets between	50 „	5	7	12
Natural abatis, in 4 rows of trees ...		—	3	3
Horizontal bough abatis, in 3 rows ...	½ of a two horse wagon load boughs 3 m. run tie rods (bindestangen) 5 pickets.	10	5	15
Standing abatis, in ditch	½ of a two horse wagon load boughs 1 m. run tie rods 2 pickets	4	2	6
Constructing wire entanglement 10m. wide	3 pickets 45 m. run strong wire 110 m. „ thin „	1½	3½	5

TABLE V. *Revetments.*

Required for	Material.	To prepare material.	To execute.	Total.
		Working hours.		
10 square metres clay revetment (Plackage)	... ...	...	5	5
10 square metres built sod revetment	800 building sods	16	16	32
10 m. run wattled do.	12 bundles, brushwood 25 pickets 8 anchors	15	13	28
10 m. run, hurdles	5 hurdles 15 anchors 15 anchor pickets,	4 exclusive of hurdles.	8	12
10 m. run gabion do.	16 gabions 5 anchors 5 anchor pickets,	2 exclusive of gabions.	8	10
10 square metres fascine do., or 40 running metres of fascines ...	12 fascines 6 anchors 40 pickets,	5 exclusive of fascines.	12	17
10 square metres wood revetment ...	10 s. m. boards or planks 20 pickets 10 anchors	8	6	14

TABLE VI.

Strength of Troops for carrying out Revetments and Obstacles.

Work.	Men.
Cutting brushwood	8 to 10
Cutting sods...	4
Wattling hurdles ... ... }	3
„ gabions ... ... }	
Binding fascines	5 to 6
Plastering (Plackage)	4
Revetting with sods ... ... }	4
„ „ planks ... ... }	
„ „ brushwood ... ... }	
„ „ hurdles ... ... }	
„ „ gabions ... ... }	
„ „ fascines	8
Palisading—	
a. Excavation of trench	8
b. Setting up the palisades	8
Obstacle pickets ... ... }	4 to 8
Harrows ... ... }	
Wire entanglement	6 to 12
Military pits...	at pleasure
Tree abatis	8 to 20
Bough abatis—	
a. Excavation of trench	6 to 8
b. Laying the boughs	6 to 8

TABLE VII.

Determination of Weights and Expenditure of force in Transports.

1 Man carries by himself ... ... 25 kilogrammes.
1 „ carries in a handbarrow ... ... 50 „
1 „ pushes in a wheelbarrow ... ... 75 „
1 Horse draws ... ... 375 to 500 „
1 Man with a load travels ... ... 50 to 80 metres in 1 minute.
1 Journey of a wagon, including loading and unloading ... ... } 800 metres in the hour, there and back.
To load and unload are required ... ... 4 men.

Weights.		Load for horse.	Barrow load for a man.
1 cubic m. soft wood ...	640 kilo.	·6 cubic m. wood.	·6 cubic m. Wood.
1 „ hard „ ...	800 „	6 Palisades.	⅛ Palisade.
1 Pointed palisade	60 to 100 „	15 Bundles brushwood.	1 Bundle brushwood.
1 Breast palisade	35 to 50 „	500 Pickets.	20 to 30 Pickets.
1 Bundle brushwood ·3 m. thick	25 „	8 to 10 Fascines.	1 Fascine.
100 Pickets	50 to 150 „	10 Gabions.	1 Gabion.
10 m. poles	15 „	10 Hurdles.	1 Hurdle.
1 Fascine	40 „	60 Building sods.	5 Building sods.
1 Gabion	30 to 40 „	30 Surface sods.	3 Surface sods.
1 Hurdle	40 „	2 Iron rails (railway).	
1 Building Sod	7 „		
1 Surface Sod...	14 „		
Iron rails (railway) about 6 m. long	185 to 225 „		
1 cubic m. light } earth	1000 „		
1 „ middling } earth	1500 „		
1 „ heavy } earth	2000 „		

TABLE VIII.

Weights and Measures.

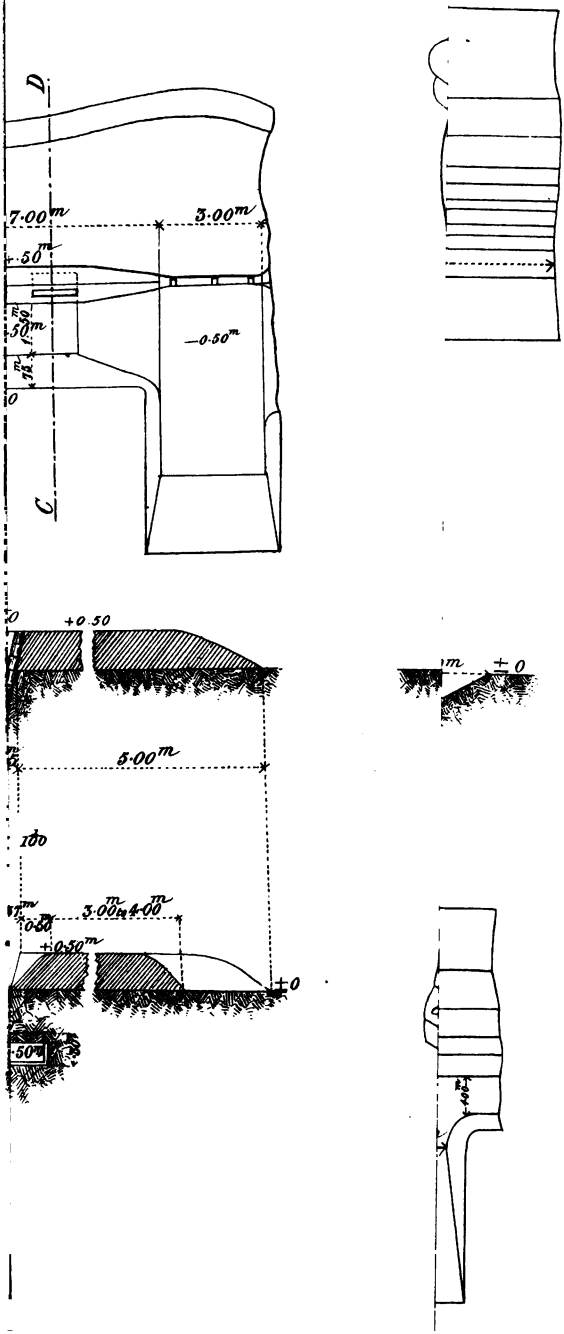
1 Milligramme ... = 0·01544 Grains (Troy).
1 Centigramme ... = 10 Milligrammes.
1 Decigramme ... = 10 Centigrammes.
1 Gramme ... ... = 10 Decigrammes.
10 „ ... ... = 1 Decagramme.
100 „ ... ... = 1 Hectogramme.
1000 „ ... ... = 1 Kilogramme.
10 Kilogrammes ... = 1 Myriagramme.
100 „ ... = 1 Quintal.
1,000 „ ... = 1 Millier.

1 Kilogramme ... = 2·2055 lbs. (Avordupois).

1 Metre ... ... = 1·0936 Yards = 40 inches, in round numbers.
1 Square metre ... = 1·196 Square yards.
1 Cubic „ ... = 1·338 Cubic yards.

1 Millimetre ... ... = 0·039370788 Inches.
10 „ ... ... = 1 Centimetre.
100 „ ... ... = 1 Decimetre.
1000 „ ... ... = 1 Metre.
10 Metre ... ... = 1 Decametre.
100 „ ... ... = 1 Hectametre.
1000 „ ... ... = 1 Kilometre.
10,000 „ ... ... = 1 Myriametre.

PLATE 2.



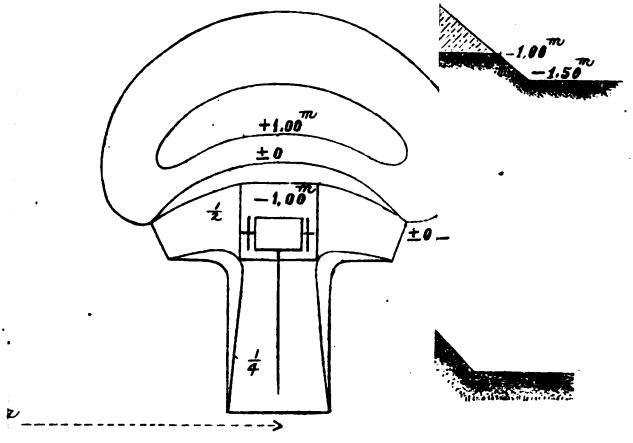


Fig. 20.

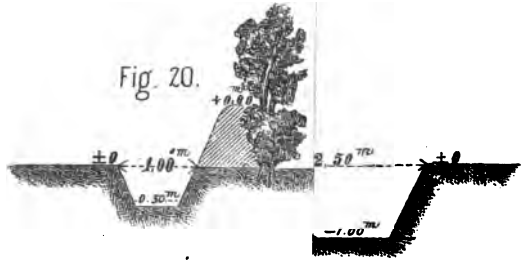


Fig. 22.

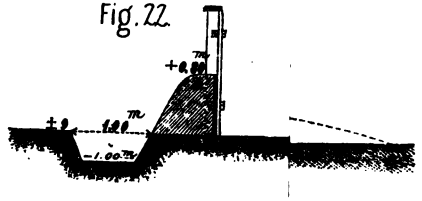
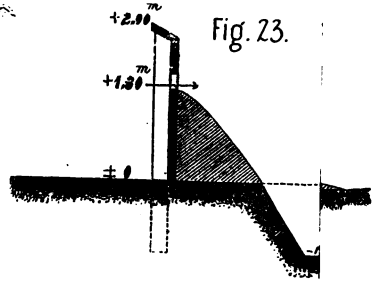


Fig. 23.



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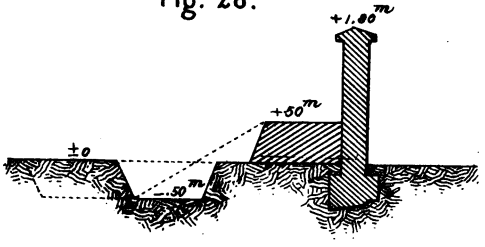

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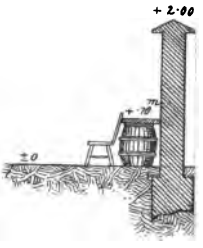

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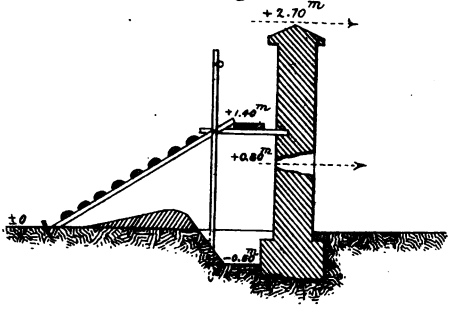

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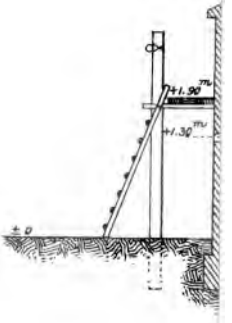

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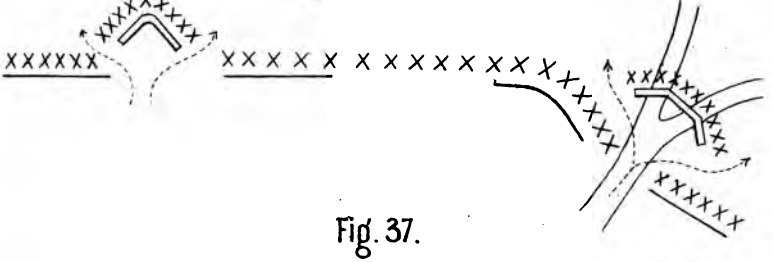

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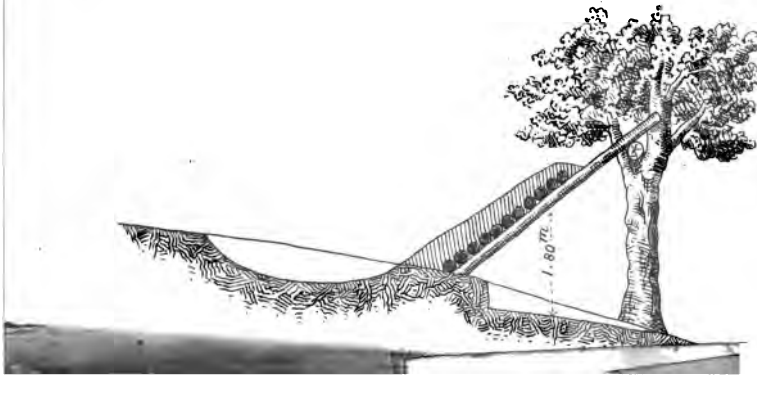

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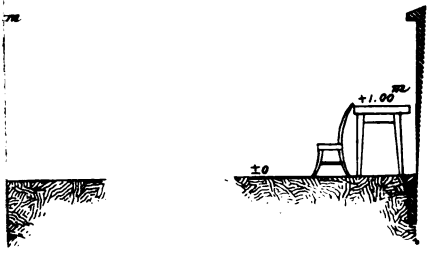

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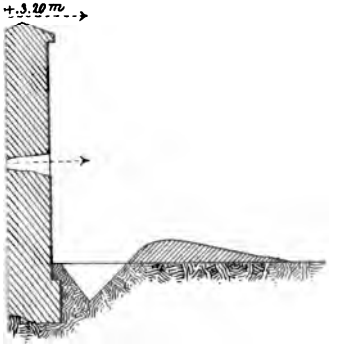

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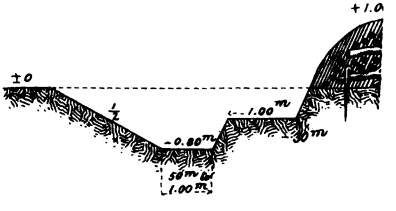

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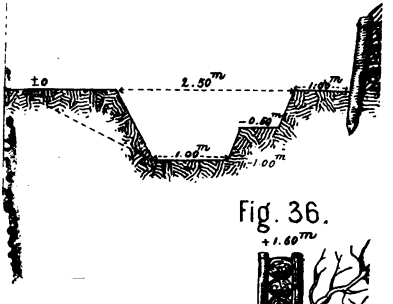

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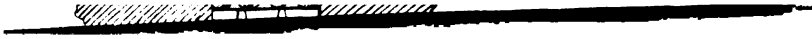

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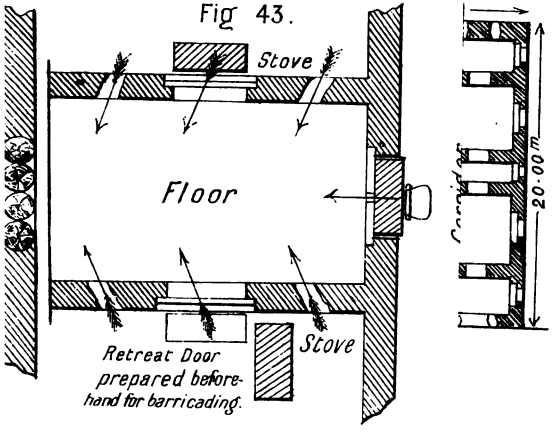

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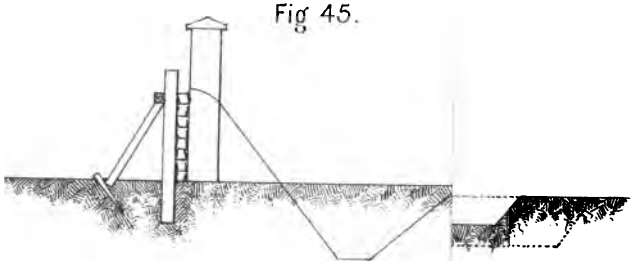

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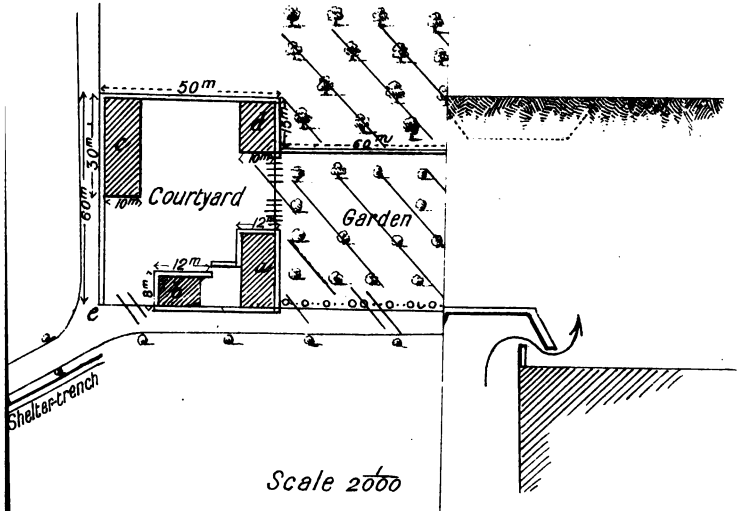
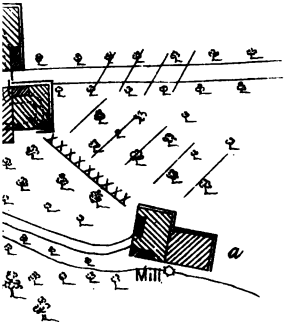


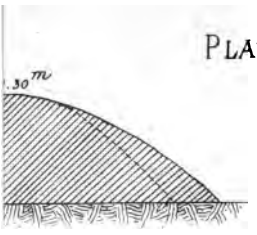
PLATE 6.

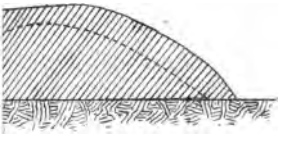
Connecting Shelter trenches

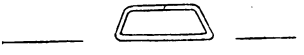
Abatis.

Boundary fences opened up. Houses demolished. Trees felled. Communications.









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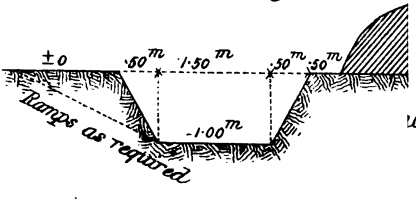

ui

trench

e 1/150

lope. g-h. Exterior ditch.

est. h-i. Glacis.

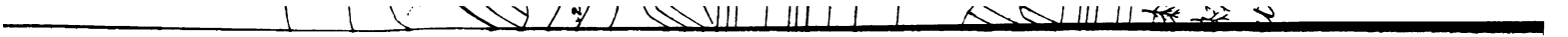

PLATE 7.

Fig 6

Scale 5

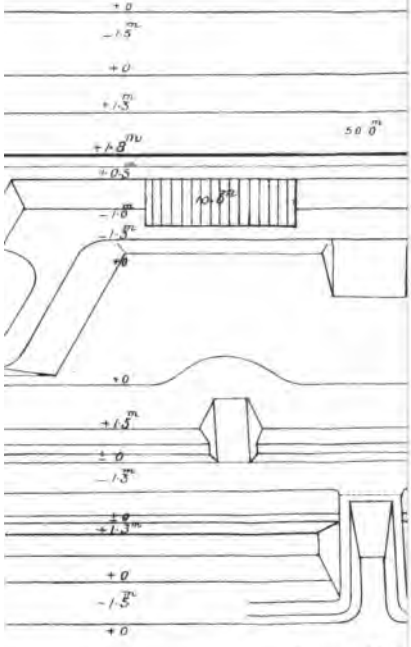

Fig 60

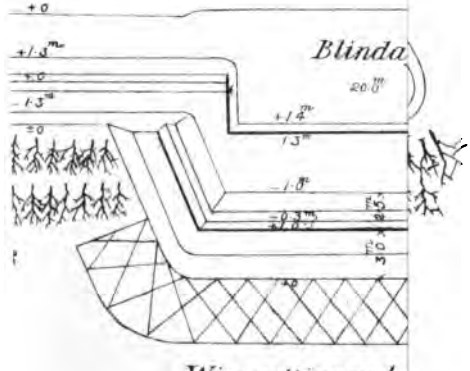

PLATE 8.

Fig. 61.

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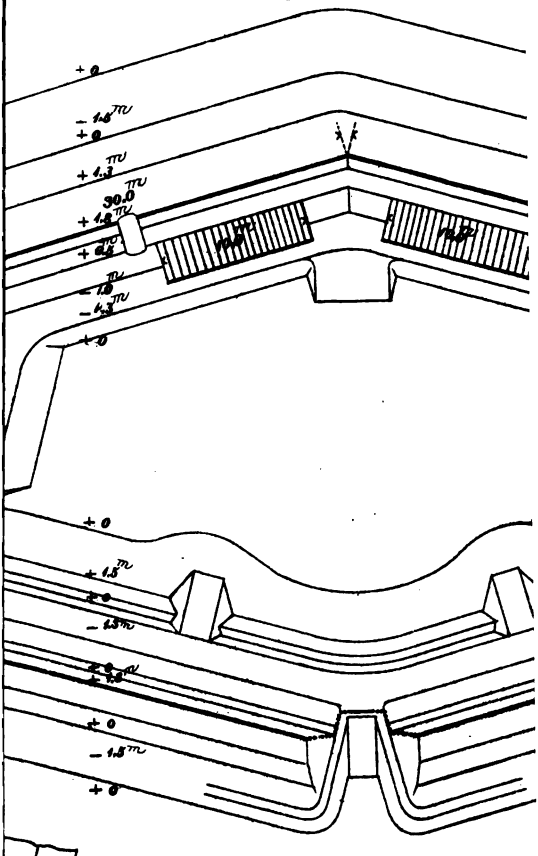

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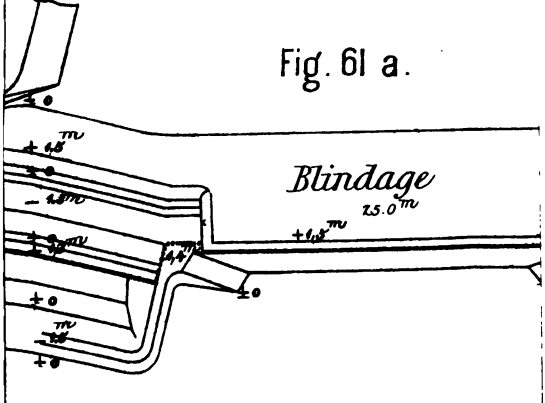


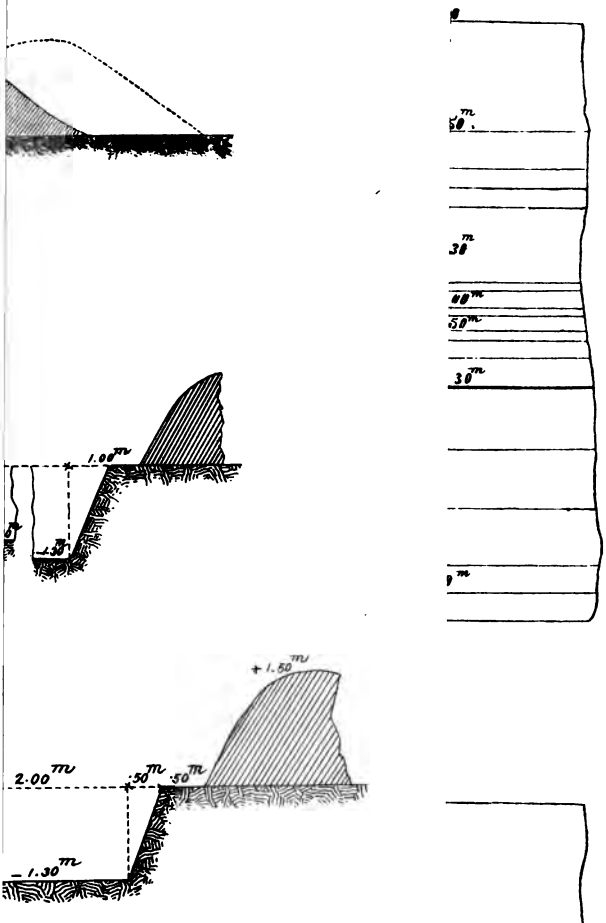
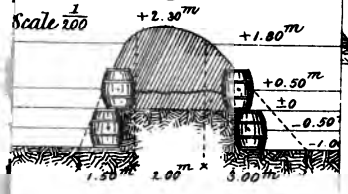
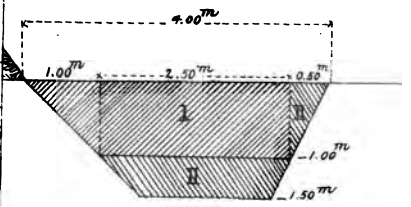

1.00m
-.30m
+1.50m
2.00m
.50m
.50m
-1.30m
+1.50m
dge +0.80m
±0
1,50m
2,00m
-1,00m
-1.30m

Fig 66.

Fig. 70.



1. Exterior ditch.



2. Interior trench.

Fig. 71.

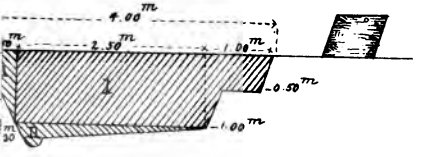


Fig 72.

3. Gorge

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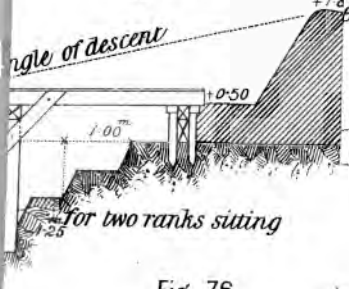

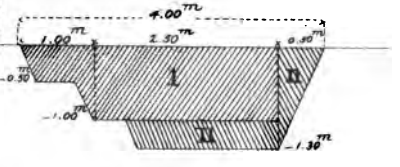

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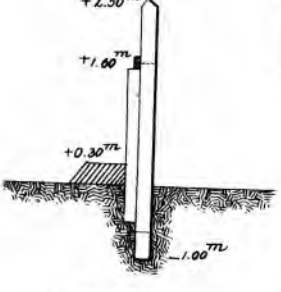
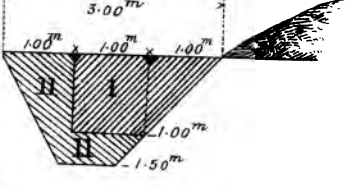
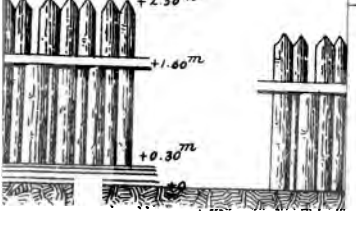


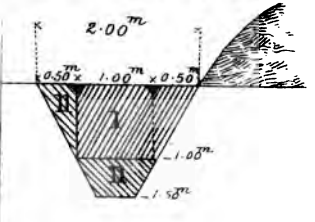
Exterior Ditch.



C. Ditch at end Profile

Fig. 78.





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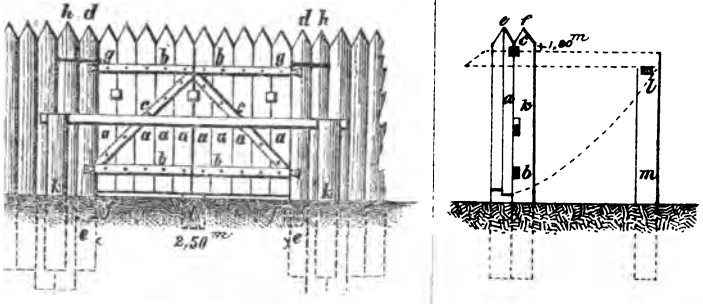

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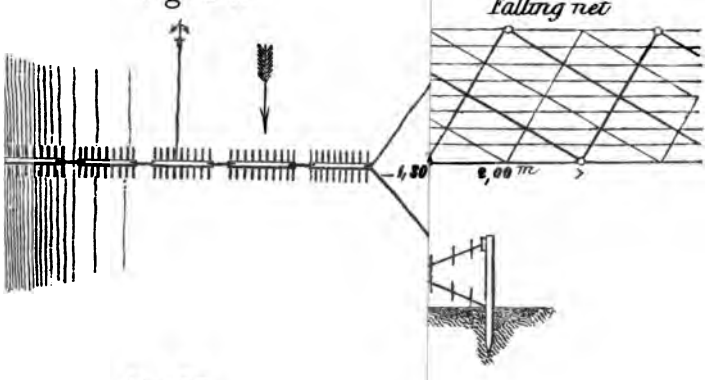

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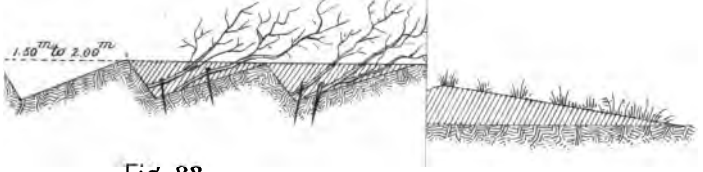
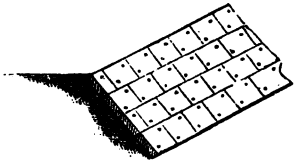


Fig. 88.

Fig. 91.



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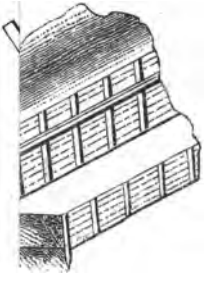

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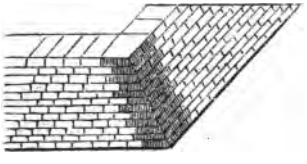

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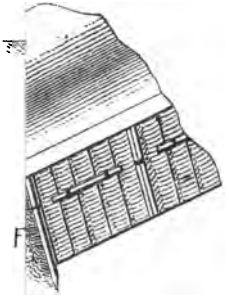

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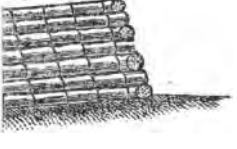

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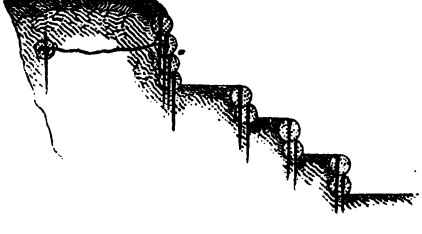

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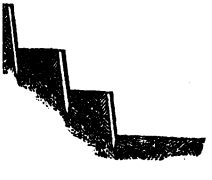

1878.

Vol. I. No. 2.

ROYAL ENGINEER INSTITUTE.

TRANSLATIONS.

RAILWAY WORKS

IN CONNECTION WITH AN

ARMY IN THE FIELD:

FORMING THE SECOND DIVISION OF THE
AUSTRIAN GUIDE TO RAILWAYS.
VIENNA, 1872.

TRANSLATED BY

LIEUTENANT H. L. JESSEP, R.E.

[ENTERED AT STATIONERS' HALL.]

Printed by
SPOTTISWOODE & CO., NEW-STREET SQUARE, LONDON,

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PART I.

DEMOLITION OF RAILWAYS.

CHAPTER I.

§ 1.

Introductory Remarks.

In order to deprive an adversary of the use of a line of railway for purposes of traffic—or, in other words, to render the line unserviceable—either the entire line, or only portions of it, may have to be temporarily made useless, or utterly destroyed, according to circumstances. In every case, the withdrawal of all unnecessary rolling-stock should be the first measure adopted. Simultaneously with this, all reserves of railway plant, and the most important tools, &c., should be removed from the stations, as well as all individuals entrusted with the technical working of the railway; the signals, first the electric, and then the visual, should be destroyed.

The simplest means of rendering the actual line impracticable is the removal of the permanent way, and when this is done throughout a considerable length it is one of the most effectual means of delaying an enemy. The restoration of the permanent way generally occasions considerable delay, and when it has been removed from a great length of railway, the enemy cannot at once bring up the necessary material for the restoration of the line, but is compelled to collect it first of all at stations, often far-distant, and thence to bring it on to the point required. It is most important that the separate component parts of the permanent way should be withdrawn entire, in order that they may be secured for future use.

Wooden sleepers should, therefore, only be cut up or burnt, when their removal is impossible; and only in such a case should the enemy be deprived of the rails and their fastenings, by sinking them in the nearest water, burying them in the ground, &c. If the formation level as well as the permanent way be destroyed, the most lasting interruption to the traffic is attained.

It may, however, happen, that by demolishing individual portions of the railway, such as bridges, viaducts, &c., the object in view may be more quickly or more thoroughly attained than by destroying the permanent way.

If stations occur on the line, they must, in order to effectually interrupt the traffic, be rendered useless to the enemy, at least, in the first instance.

This can only be accomplished by the removal of such plant about the station as is the most important and the most difficult to replace—such as water-pipes, sidings, point-levers, points, &c.

In the following pages it will be shown how the various parts of a railway may generally be made unserviceable.

CHAPTER II.

Main Works.

§ 2.

Embankments.

Embankments may be made unserviceable either by erecting barricades across them, or by cutting through them transversely. The former method is so simple, that no further remark need be made upon it; the effect produced can never be anything but slight. The embankment should only be cut through when the removal of the permanent way alone is considered to form too slight an obstacle, or when no more suitable object for destruction is found on the line. But since a railway embankment may serve as a dam in the event of an inundation, or as a protection against sudden and destructive floods, the causing of a breach on friendly territory would appear to be in no case advisable: and even in an enemy's country, embankments should only be broken through when by this means an extremely important end, attainable in no other way, is to be arrived at, and when there is no possibility of their being of any service in connection with the positions and movements of friendly troops. The partial destruction, therefore, of embankments should only be ordered by the general commanding-in-chief, who alone is in a position to judge of all the circumstances in connection therewith.

The highest portions of an embankment should be chosen for demolition; and also, if possible, such points as are unapproachable from both sides—as, for instance, where the line runs through a marsh; for in such a case, the simultaneous restoration of several destroyed portions becomes almost impossible. The demolition may be effected

either by blowing up, or by forming a gap by manual labour. The latter plan is to be preferred when it is possible to work at several places at once; each cut should be at least 10 feet or 12 feet deep, and and from 30 feet to 36 feet long. The excavated material is, with high embankments, thrown over the slopes, but with lower ones it is scattered about. If the embankment is carried along the side of a river, and is not at the same time a protection against inundations, and a safe escape may be provided for the water flowing through, a length of 5 feet to 6 feet suffices for the opening, if its sides are made vertical, and from 1 feet to 2 feet below the level of the water, because then the water flowing through will wash away by degrees the vertical sides, and the obstacle will become continually broader.

To calculate the labour and time necessary for such work, the following statement may serve as a guide: 56 men, in from 8 to 10 hours, in average soil, can make an opening 30 feet long, 10 deep, and 24 feet wide, supposing the slopes to extend to the full height of the embankment, and the earth to be thrown down over them. This gives, consequently, in 8 working hours 21 cubic feet excavated per man per hour; in 10 working hours, 17 cubic feet.

Note.—The regulation strength of a military detachment of a field railway division is 56 men; in all the following demolitions, the calculations of work done and the distribution of the workmen are made with this understanding.

Cuttings.

Cuttings may have barriers formed across them, or they may be filled up. Barriers made with rolling stock, &c., form, as in the case of embankments, only a very slight obstacle; their employment, however, in deep and long cuttings, appears advisable when there is only a short time at command, or when the adversary is only to be checked for a little while, for the removal of the materials employed is in this case much more difficult than in that of embankments. The kind of barrier to erect, as well as the time, workmen, and material required depend entirely on local circumstances; this point will therefore not be further touched upon.

Cuttings may be filled up either by digging or by blowing in the sides; in most cases, the deepest places are the most favourable. A cutting should be filled up for a length of from 30 feet to 36 feet at least, and to a height of from 4 feet to 6 feet. The data given in the case of embankments as to the calculation of the work will also serve here.

Tunnels.

Tunnels may be rendered impassable either by blowing in, by barricading, or by a combination of the two.

The barricading may be carried out in various ways. Without excluding other possible arrangements, a method of proceeding will here be given, which can generally be carried out. Near the middle of the tunnel, several rails are taken up and formed into a barrier; when possible, grooves are cut out in the sides of the tunnel, and in these the extremities of the piled up rails are placed and tightly wedged. To complete the barricade, a train of (if possible) *loaded* trucks is pushed into the tunnel at a rate of from 35 to 45 miles an hour by one or two engines. When the train approaches the barricade, where the rails have been taken up, the first truck leaves the rails, the others become heaped up on one another, and a formidable barricade is the result. If it is desired to block a tunnel both by barricading and by blowing in, the barricade is formed at the centre, and the tunnel is blown in at each extremity.

Note.—In the Franco-German War of 1870-1871, on the railway from Metz, by Thionville, Montmédi, and Mezières, to Paris, the French blew in the tunnel at Montmédi at each end for a length of 34 feet and 140 feet respectively, and filled the remaining space in the centre with locomotives, trucks, &c.

§ 3.

Bridges in General.

By the destruction of bridges or viaducts, a most serious check may be given to an adversary in a short time, and with but little labour, and this is most especially the case when interruption of communication over a considerable length is effected. But as the restoration of destroyed bridges and viaducts requires some time, their utilisation for one's own purposes will be retarded; they should, therefore, only be destroyed in the following cases:—

(*a*) When there is neither time nor means at disposal to effect the removal of the permanent way, or to offer such other hindrances to the proper working of the bridge as will check the adversary for the time intended. In this case only the largest bridges should be destroyed, those of from 12 feet to 30 feet span being disregarded.

(*b*) When by the removal of the permanent way, and even by forming other hindrances to working, the object in view cannot be attained. In this case even the smallest bridges should be destroyed, especially if many of these occur one after another; because even if

their restoration requires no considerable time, the adversary is nevertheless prevented from replacing the permanent way simultaneously at several points thus cut off from each other by the demolitions.

(*c*) When a complete demolition is specially ordered by the Commander-in-Chief. This would probably occur in the case of large bridges, likely to be of importance in the course of operations; the commanding officer (for the reason already given in speaking of embankments) is then the only person in a position to decide on the advisability of a demolition, as well as on its extent.

The means by which bridges may generally be rendered unserviceable are:—

(*a*) The entire or partial removal of the several portions of the construction.

(*b*) Burning.

(*c*) Blowing up.

The material, and partly also the construction of bridges, always admit of one or more of these measures being adopted. If the communication is not to be entirely destroyed, but is, which is most likely, only to be interrupted for a length corresponding to the object in view, the demolition should be most thoroughly carried out at the end of the bridge furthest from the enemy.

§ 4.

Stone Bridges.

These can only be demolished by blowing up.

§ 5.

Wooden Bridges.

Wooden bridges, owing to their usually simple construction, and to the destructible materials of which they are formed, may be rendered unserviceable more readily than any other kind of bridge. If the delay occasioned is intended to be of short duration, it will be sufficient to render only the roadway unserviceable; but if the communication is to be interrupted for a longer time, the supports of the bridge must be entirely or partially demolished after the roadway is destroyed; this is essential in the case of those wooden constructions which rest on stone piers or iron columns. If a considerable interruption of the communication is intended the supports should only be left intact when either their distance apart is so great that the adversary would probably be compelled to erect temporary piers for the restoration of the bridge, or when the necessary time and labour are wanting.

(*a*) *Removal.*—In all wooden constructions with vertical supports, the rails and sleepers are taken up and removed, as on the open line. (§ 8.)

With pile bridges, suspended and trussed bridges, or with combinations of the two last, the side pieces must be taken away, and the longitudinal bearers at the near end of the bridge, together with the sleepers, removed, in order to be loaded into trucks, and then taken to the nearest safe station. But should the necessary rolling stock for this purpose not be at hand, or if time is wanting, these portions of the construction should either be thrown into the water and floated down stream, or towards the near shore, or, if there is no water, they should be sawn in two. However, as this last method occupies considerable time, it is generally more advantageous to burn these portions.

With trussed bridges, after the removal of the longitudinals, the vertical pieces *cc* (*Plate I., figs.* 1, 2, and 3) must be taken down, and afterwards cut through; with bridges on Howe's system, the transoms *k* must be removed or sawn through. But the delay thus occasioned is but slight.

Bridges made after Howe's method may also be taken entirely to pieces; the vertical screw-ties *c* (*Plate I., figs.* 3 and 4) being screwed off, after the removal of the rails, sleepers, and transoms, and the beams *b* being taken away or sawn through, after the removal of the braces *a*. Such a proceeding would, however, require considerable time. It may be thought desirable to destroy or remove merely a portion of the structure, and so cause a weakness in the construction, the extent of which, however, cannot be estimated at the moment of execution. It has, in fact, been practically shown that a Howe bridge, of which a number of braces on one side had been completely smashed by an engine leaving the rails, was perfectly well able to bear all the vibration and work connected with replacing the engine on the rails, without any further injury to the bridge.

But, as a rule, a mere weakening of the structure, whether effected by the removal of certain parts, or by just sawing the bearers through, will have little prospect of success; for a prudent adversary (and such an one must always be assumed) would make use of no bridges which had not first been thoroughly examined. And when once damage of slight importance has been discovered, the bridge may be rendered available for traffic in a short time with the help of struts, props, &c.

The number of workmen required varies according to the nature of the demolition; it can no more be fixed than can the time required.

Rendering wooden bridges, with vertical supports, unserviceable may be effected most quickly, most surely, and with the least expen-

diture of labour, by the removal of individual portions of the construction. The complete removal of a bridge would generally only be an advantage when it was wished to keep the materials. But in order that this may be possible either the near bank must be completely secured from seizure by the enemy, or the means must exist of sending these materials to a safe place; under all other circumstances the materials must, as far as possible, be destroyed, in order to deprive the enemy of their use; and in effecting this both time and labour would be judiciously expended.

With bridges of boats, the connection lengthwise between the boats must be severed, the anchors in the bed of the river raised, and the cables laid on shore, after which nothing stands in the way of the removal of the boats.

To give some idea of the time necessary for this, it may be noted that the opening of the cut in the railway bridge at Mapau is accomplished in from 7 to 10 minutes.

With flying bridges the boats must be taken away, and the ramps or landing places rendered useless in the manner described for pile bridges.

(*b*) *Burning.*—Notwithstanding the great disadvantage of a demolition by burning, that the limits of the fire cannot be exactly laid down, this, the only sure means adopted up to the present, must be made use of in all those cases in which a lasting and rapid destruction of the communication is contemplated.

The chief condition in the attainment of a satisfactory result in the burning of a bridge is a sufficient draught of air. In order to effect this the ballast must be removed and the woodwork exposed. The inflammable materials—such as straw, brushwood, pitch, tar, petroleum, &c.—are then spread over the different parts of the bridge.

Tarred hoops, or lumps of pitch, may be secured to the piles, &c., care being taken not to press them down too closely to the wood-work; small pieces of touch-wood should be attached to the hoops, &c. The spaces between the piles are filled up with brushwood or straw, the piles themselves being smeared, if possible, with pitch or tar.

Chaldrons filled with petroleum may be hung up under the roadway. Where stone piers occur, stacks of wood should be piled upon them.

Setting fire to the bridge is most simply effected by hand, but Bickford's fuze or hose may also be used. The quantity of the materials necessary for burning a wooden bridge cannot be laid down, as it varies under different circumstances. The nature of the wood, its dryness and age, the season of the year and temperature, the strength and direction of the currents of air, &c., determine, in each particular case, the

expenditure of combustibles. A detachment of 56 men under favourable circumstances can prepare for burning 4 sets of piles, or 5 bays, in about 5 hours.

§ 6.

Iron Bridges.

With iron bridges interruption of the railway traffic may be attained by the removal of separate parts of the construction. But this can only be carried out when the connection between the parts is effected by screws. Where rivets are used, on the other hand, as is the case in all new bridges, this proceeding is not practicable, for it is impossible in a short time to break through all the rivets at the points of connection;* in most cases, by the removal of only some of them merely a weakness in the construction would ensue, against causing which a caution has already been given in speaking of wooden bridges. Merely striking off the heads of the rivets is quite useless.

In the following table every kind of iron bridge, with the exception of suspension† and swing bridges, is taken, and, with each particular bridge, those parts which when detached would make the bridge useless for railway traffic are mentioned.

* The truss bridge, 372 feet long, over the March at Kojetin, for example, has over 60,000 rivets.

† The rendering unserviceable of the suspension bridge over the Elbe at Tetschen, near Bodenbach, in the campaign of 1866, was accomplished by taking away the side-pieces, and unscrewing the vertical rods, for which purpose scaffolding had been erected beforehand, and the screws oiled. The unscrewing of the vertical rods was accomplished by 28 men in 35 minutes. This, although only a road-bridge, nevertheless affords some guide in rendering railway suspension bridges unserviceable, as the principle of their construction is the same.

Nature of bridge.			To remove.			How the construction may be further weakened, or entirely taken down.
MATERIAL.	CONSTRUCTION.		Sleepers (after removal of rails).	Transverse girders and binding beams.	Longitudinal girders.	
CAST IRON.	STRAIGHT GIRDERS.	Bridges of beams (*Plate* II. *figs.* 1–5).	With girders of a U-shaped section, unfasten the screw-bolts *x* (*Fig.* 5). With girders of a T- and I-shaped section, take out the screws *z* (*Figs.* 3, 4).		Unfasten the screw-bolts *d* (*Fig.* 3), and remove the distance-pieces *h* (*Figs.* 2, 3).	
		Suspended bridges (*Plate* II. *figs.* 7, 7*a*, *b*, *c*, and 8).	Detach the longitudinal sleepers *o* from the cross-girders *k* by taking out the screw *p*. The sleepers may also be sawn through.	After the removal of the longitudinal sleepers, detach the supports *k* by unscrewing the nuts *n* on the ties *f*.		The ties *f* are set free by unfastening the screw-bolts *e*; the compression booms *a* and struts *b* are separated by taking away the screws *d*, passing through the flanges; the tension booms *h*, by taking away the nuts *z*, are divided into their two parts, and the struts *b* freed from the piers; the bolts passing through the foot-plates *g* are then removed.
		Trussed bridges (*Plate* II. *figs.* 9–11).	Lift the longitudinal sleepers from the chairs *f*.			By undoing the distance-pieces *k*, and the screws *v*, or by removing the horizontal stiffeners, which is effected by undoing the screws in the plate *s*, and the screws *q*.
	ARCHED BRIDGES.	Arch below railway (*Plate* III. *figs.* 1, 2).	Remove the longitudinal sleepers after undoing the screw-bolts *z*, or saw them through (*Fig.* 2).	Remove the binding beams *u* after undoing the screw-bolts *r* (*Fig.* 1).		The vertical rods *p* are detached by undoing the screw-bolts *q* and *s*.
		Arch over railway (*Plate* III. *figs.* 3, 4).	As on the open line.			
	ARCHED RIBS.	Trussed bridges. Arch below or above roadway (*Plate* III. *figs.* 5, 6).	Remove the longitudinal sleepers L after undoing the screw bolts M; or, saw the sleepers through.	Remove the binding beams E after undoing the screw-bolts F.		By removing the screw-bolts D, after which the vertical rods A may be taken out.

Nature of bridge.			To remove.			How the construction may be further weakened, or entirely taken down.
Material.	Construction.		Sleepers (after removal of rails).	Transverse girders and binding beams.	Longitudinal girders.	
Wrought Iron.	Straight Booms.	Plate-girder bridges (*Plate* II. *figs.* 1-4).	As for cast-iron plate-girders, except that the U-shaped section of girder does not occur.		As for plate-girder bridges of cast iron.	
		Box-plate girders (*Plate* III. *figs.* 7-12).	Remove the transverse sleepers *h* (resting on the upper boom) after undoing the screws (*Fig.* 10). Remove the longitudinal sleepers *l* (resting inside the booms), by undoing the screws *m*, *n*, *o*. (*Fig.* 7.)			
		Lattice-girder bridges (*Plate* IV., V.).	Remove the longitudinal sleepers *l*, whether the roadway is carried on the upper boom or at the centre, or lower boom, after undoing the screws *m* (*Plate* IV., *figs.* 7, 8; *Plate* V., *fig.* 2). Remove the transverse sleepers *c* by undoing the screws *d*. (*Plate* V., *fig.* 1.)			
Wrought and Cast Iron Combined.		Arched Ribs (*Plate* VI. *figs.* 1, 2, 3).	Remove the transverse sleepers *m*, from the blocks to which they are riveted.			With the help of windlasses, the bridge may be raised from its supports, and thrown down.
		Neville's System (*Plate* VI. *figs.* 4, 5).	Remove the longitudinal sleepers *m*, after loosening the screws *q*. Remove the baulks *g*, or saw them in two, or burn them.	Remove the cross-girders *d* after undoing the screws *z* in the chairs *f*; or saw them in two, or burn them.		By undoing the screws *h* and *o*, by which the struts *a* are connected with the booms *b* and the latter with the end pillars *l*; by taking away the distance-pieces R, and the cross-bracing.
		Schiffkorn's System (*Plate* VI. *figs.* 6, 7).	Remove the longitudinal sleepers *v*, after undoing the screws *m*; or cut them through.	Remove the cross-girders *a* after undoing the screws *o'* and *p*.		By taking away the screws *f*, *g* and *t* by which the booms and cross-pieces *c* are separated from each other, and the former from the end pillars *b*; then remove the circular bars *d* by undoing the screws *s*.

With the help of this table the following facts may be established concerning the degree of unserviceableness to which iron bridges may be reduced by the removal of their individual parts.

(*a*) The permanent way can in all cases be removed; this, in the case of bridges, will cause an enemy more delay than an equal amount of demolition on the open line; because, with the one exception of arched bridges (the arch over the railway), the sleepers must either be fixed by a mechanical contrivance or secured with screws and nails.

(*b*) The transverse girders can only be removed from bridges on Neville's and Schiffkorn's systems. The delay thus caused, judging from the time necessary for restoration, as shown by experience, is considerable.*

(*c*) Where binding beams occur they may always be taken away. By so doing great delay would be caused only in the case of large spans.

(*d*) The removal of longitudinal girders is only possible with bridges of beams. The time required for this is not compensated for by the slight obstacle caused.

(*e*) A further weakening of the construction is only possible where connections by screws occur, but it will never be attended with anything but slight success, unless it is thoroughly effected, which, in most cases, time does not permit.

(*f*) Throwing the bridge bodily down is only practicable with very small spans. To accomplish it there must be extremely powerful windlasses at hand, the bridge must be of small weight, the piers must be without bolts (as in the case of arched wrought iron bridges), and the workmen at the windlass must have a secure foothold on the piers.†

The requisite number of workmen and length of time for removing individual portions cannot, as a rule, be fixed, as the numbers depend on so many different circumstances. For removing rails and sleepers the same numbers apply as for an equal length of permanent way on the open line.

* The campaign of 1866 in Bohemia furnishes the following facts:—

On three Schiffkorn bridges of 124 feet span, on the Turnau-Kraluper railway, the iron cross-girders were removed from a central span, after taking up the permanent way &c.; this was completed at each bridge by 14 men of the Engineer Troop, besides railway labourers, in three hours, while the temporary restoration effected by the Prussians occupied about three days on each of these bridges.

† The removal of the bridge by drawing back the whole construction, which has been sometimes proposed, is, under all circumstances, extremely difficult, and in time of war, utterly impracticable.

CHAPTER III.

PERMANENT WAY.

§ 7.

Extent of the Demolition.

The extent to which the removal of the permanent way is to be carried depends, in this, and in all cases of demolition, on the delay which it is intended to cause the enemy.

With an equal number of workmen the temporary restoration of the permanent way, with the materials at hand, takes about nine times as long as its removal, as will be shown afterwards (§ 22); the amount of demolition to be effected, therefore, can be approximately fixed in every case by the delay intended to be caused.

Under certain circumstances it may be advisable to remove the permanent way only here and there, leaving short lengths intact. By this means a given length of unserviceable roadway is spread over a considerable distance. Although this cannot be done in every case in which a partial removal of the permanent way seems advisable, yet some particular circumstances will now be pointed out, under which this proceeding may be advantageous on a single-line railway.

(*a*) If the material removed is to be conveyed away it is advantageous; because in this case the work of demolition can proceed very quickly, as a certain amount of work (§ 8) may be carried on on that portion of the line subsequently to be taken up, lying behind the removing trucks.

(*b*) It is advantageous, if it is known that the adversary can procure no equally long rails; he is then compelled to employ the rails which he has brought with him; these have to be fitted into the gaps caused by the partial removal of the permanent way, and must consequently be shortened, or else the rails left intact must be taken up, in which much time and labour is expended.

(*c*) If, under the above-mentioned suppositions, many curves occur, it is advantageous; for on account of the rails employed being of unequal length, what is said under (*b*) applies still more forcibly. Curves, being the most difficult portions of a railway to restore, should only be left untouched when there is a prospect of the line being very soon required for use.

No rule can be laid down as to the proper length of permanent way to be left* or removed in the case of a single line; but that the

* The German lines have rails in 18 feet, 21 feet, and 24 feet lengths. The Russian lines have rails of 14 feet and 20 feet lengths.

portion left must not be shorter than the length of the train of trucks is evident.

In the case of a double line, at least one pair of rails must be entirely removed, and the other partially so; otherwise, an adversary might renounce the advantages of a double line for a time, and employ the material from one line of way to complete the partially destroyed one. As a rule, the traffic on a double line of railway is not interrupted for any length of time merely by the removal of the permanent way; for an adversary may employ the material from that portion of the line in his possession in the restoration of the line demolished; it therefore appears advisable, in any case, to ensure success, under such circumstances, by demolishing portions of the main works.

§ 8.

Removal of the Permanent Way.

As mentioned in § 1, the material composing the permanent way may either be torn up and rendered useless on the spot, or it may be taken up and carried away. The choice of the one or the other proceeding depends on the time at command and the labour available. With but little time and many workmen, the former proceeding must be adopted, and the removal of the permanent way can then be effected at several points, and even along the whole line to be destroyed, simultaneously. If, on the other hand, there are only a few workmen available, and the time is not very limited, they must all be fully employed at once which is only practicable when the material is to be entirely, or for the greater part, carried away. In this case, only a certain length of the permanent way, viz. up to the trucks intended for its transport, can be torn up simultaneously; whence the maximum number of workmen that can be employed depends upon this length.

Finally, with very limited time and labour, the mere removal of the permanent way is not sufficient, and other important parts of the line must be demolished (§ 3).

The following table shows the distribution of workmen for the removal of the permanent way without transporting the material, and also their distribution when it is transported, with the special duties of the respective parties; in both cases, it is presumed that the detachment consists of 4 superintendents, 56 skilled workmen, and a sufficient number of labourers (at least 40), and that the rails are of the Vignoles section, and rest on transverse sleepers.

(a) *Removal without Transport.*

No. of party.	Nature of work.	Number of		Tools.	Execution.
		Superintendents.	Skilled workmen.		
I.	Removal of ballast.	—	2	A shovel for each man, and a pick, if necessary.	Each man places himself by a rail-length, and clears away the ballast, which probably covers the inside spike nails and fish-plates, so that these may be removed without difficulty. When this work is completed on one rail-length, the party goes on to the next, and so on.
II.	Removal of fish-plates.	1	8	1 screw spanner, and 1 hammer, to each man.	The work of this party begins after No. I. party has left the first rail-length. The party is divided into sets of two men, who station themselves outside the rails, where the unscrewing of the nuts and striking off of the bolts may be continuously effected.
III.	Withdrawal of the spikes.	1	8	4 crow-bars, 4 hammers.	This party begins as soon as No. II. party is about one rail-length ahead. It is divided into sets of two men, one of whom uses the crowbar, and the other the hammer, to draw out the spikes on the inner side of the rails. The hammer is used as a fulcrum for the crowbar, and should only be employed to strike off the spike-heads, when the withdrawal of the spikes is attended with great difficulty; and even then, it is deemed advisable, if possible, to avoid it, as taking up too much time. The most skilful workmen should be selected for this party, as on their work depends the time occupied in the removal of the permanent way.
IV.	Removal of rails.	1	16	4 picks.	This party follows No. III. party, and is divided into two sets of eight men each, who place themselves on the inside of a rail-length. The two men near the ends of the rail are provided with picks, with which they draw the rail inwards, and endeavour to make it lie on the picks, so that it can be well seized by all the eight men; it is then raised on to their outside shoulders, and thrown down the slope, or laid on one side. When this work is finished for the first rail-length, the party advances to the next, and so on.

Removal without Transport—continued.

No. of party.	Nature of work.	Number of		Tools.	Execution.
		Superintendents.	Skilled workmen.		
V.	Lifting up and removal of sleepers.	1	16	1 pick to each man.	This party is so divided, that two men are stationed at an intermediate sleeper, and four men at a sleeper where there is a joint. The men lift up the sleepers with the picks, and drag them on one side, or shoot them down the slope.
VI.	Reserve party.	—	6	As required.	This party gives two men, who are to be provided with hammers, to No. II. party (fish-plate party), to strike off those fish-plate screws, which are very tightly fixed or rusted; these men also collect the bolts and nuts. The remaining men are employed where necessary; but most advantageously in strengthening the spike party (III).
Total.		4	56		

This division of the work might also be applied with chair-rails, except that Parties II. and III. instead of removing fish-plates and withdrawing spikes, would have to knock out the wooden or iron keys, and, if necessary, bore out the former.

The chairs are left on the sleepers. No. IV. Party would then have to lift the rails out of the chairs.

The spare workmen are to occupy themselves on both sides of the railway with preparing the sleepers for burning, with placing the rails removed on the sleepers when stacked in heaps, or with carrying them to places where they can be sunk, or with bending the rails*; for these purposes, the workmen should be suitably divided into parties under their own superintendents.

A rapid removal of the permanent way may be attained under urgent circumstances by the method frequently employed in the American Civil War, by which whole portions of the railway, consisting

* If the rails are laid upon the burning sleepers they become bent, and are thus rendered unserviceable. The simplest method of bending a rail consists in letting it fall down from some little height upon another rail lying on the ground, in such a way that it falls on its side.

of from one to two rail-lengths, together with the attached sleepers are lifted up, and thrown down from the roadway. This method ot demolition of the permanent way will be found most effectual on high embankments, for in this case the rails become thoroughly bent and unserviceable by being thrown down.

In this work, a division of 56 men may be separated into two divisions of 28 men, each division being employed for the removal of a portion of the permanent way equal to one rail-length. Of these 28 men, 8 would be employed for the removal of the ballast, so far as is necessary to enable the rails to be lifted, and 8 more for detaching the fish-plates. Then 12 men lift the rails, carry them to one side, partly laying hold by the sleepers, and partly by the rails, and throw them over the slope. With portions of permanent way consisting of two rail-lengths, 16 men would have to attend to the removal of the ballast, 16 to the removal of the fish-plates, and 24 to lifting up the rails, &c.

(*b*) *Removal with Simultaneous Transport.*

Experiments* have shown that the trucks intended to be loaded with the rails and sleepers must be stationed at a distance of 6 rail-lengths from the starting point of the work, in order that the uninterrupted progress of the work of removal of the permanent way may fit in with the carrying of the material. This arrangement would therefore be adopted with the division of labour following.

* An experiment carried out at Hohenau, 21st September 1868, has shown that the tearing up, carrying, and loading, occupied on an average—

With 3 rail-lengths, 5 minutes
„ 6 „ 7 „
„ 7 „ 11 „
„ 10 „ 18 „

Whence it appears that working with 6 rail-lengths requires proportionately the shortest time.

No. of party.	Nature of work.	Number of		Tools.	Execution.
		Superintendents.	Skilled workmen.		
I.	Removal of ballast.	—	2	As before, in removal without transport.	The work of these parties commences after the train for the removal of the material has been stationed six rail-lengths from the starting point; the work is carried out exactly in the same way as shown in the preceding table.
II.	Removal of fish-plates.	1	8		
III.	Drawing out the spike-nails.	1	8		
IV.	Removal of rails.	1	16		As before, this party takes up the rails as soon as No. III. party has left the first rail-length: they are then carried upon the inside shoulders to the trucks, and loaded on to them, where possible, at the sides.
V.	Raising and removal of sleepers.	1	8		This party merely raises the sleepers from their bed in the ballast; their removal, and the way in which it is effected by the labourers, will be mentioned later.
VI.	Reserve party.	—	6		As described in the previous table. This party can, however, be afterwards used to strengthen the loading-parties.
VII.	Loading party.	—	8		This party, with the help of the Reserve and of labourers, packs the rails and sleepers upon the trucks; these last are so arranged one behind the other, that each truck carrying rails is immediately followed by one carrying the sleepers belonging to them.
Total.		4	56.		

The labourers for carrying the sleepers are posted 4 at each intermediate sleeper, and 6 at each sleeper under a joint. From the labourers are also chosen the reinforcement which will probably be necessary

for the loading-party; consequently, about 40 labourers in all are required.

When the work on 6 rail-lengths is completed, the train advances this distance, and the demolition is repeated in the manner already described.

When the permanent way is only removed here and there, and the train is standing where the line is intact, Nos. I. and II. parties pass the train and work in front of it. In all other cases, the parties wait to begin their work forward, until the train has taken up its new position.

When the necessity of removing the permanent way for a certain length can be foreseen with certainty, it is very advantageous, some time before the commencement of actual work, to remove the ballasting, and take off the fish-plates, as by this preparatory measure the effective result is increased, without necessitating an interruption to the traffic until the actual demolition is begun.

In calculating the number of trucks (lorries) necessary for the transport of the material of the permanent way, it may be taken as a guide, that one truck has a carrying power of 200 cwt.; it may therefore be loaded with 50 rails, or with the sleepers belonging to that number. Hence may be derived the number of trucks, and also the length of the train, which, besides the necessary open trucks (lorries), must have a truck for tools, one for the men, and a locomotive and tender. A double line of rails should have, when possible, one train for each pair.

§ 9.

Working Power of a Division.

From a trial especially arranged to ascertain the working power of a division of workmen, the following results were deduced, which, however, only hold good during the first hour of work. If, therefore, an equal amount of work is to be attained in each successive hour, there must be a fresh relief every hour.

(*a*) *Removal without transport.*—A division consisting of 4 superintendents and 56 skilled workmen, besides the number of labourers given in § 8, can demolish a length of about 610 feet of permanent way* (29 rail-lengths, each of 21 feet) in about one hour, and remove the material as shown above. In this case, several distinct parties may be arranged at discretion, and the same amount of work obtained

* At Hohenau, 48 thoroughly skilled workmen demolished a length of 29 rails, each of 18 feet (about 520 feet), in 46 minutes, and loaded the rails only on the trucks. Before the commencement of the work, the ballast and two screw-bolts from each fish-plate had been removed.

from each; the result will then be increased proportionally to the number of the parties. Thus, for example, two parties of the above strength will be able to remove about two miles of superstructure in 10 hours.

(*b*) *Removal with simultaneous transport.*—A division consisting of 4 superintendents, 56 skilled workmen, and 40 labourers, can remove a length of 610 feet in 1½ hours, and load the material on trucks. To effect this, the trucks are stationed 6 rail-lengths off, but only a double number of men at the outside can be organised without the parties interfering with each other's work in the limited space. As the working-power in this case is in the proportion of about 1½ to 1 to that in the former, these two united divisions would demolish about 2 miles of permanent way, and load it on the trucks, in about 15 hours.

CHAPTER IV.

Stations, Rolling-stock, Signals.

§ 10.

Points, Crossings, &c.

The simplest means of depriving an adversary of the use of a station in a short time consists in the entire removal of the permanent way. This means can, however, only be employed when not more than 3 or 4 lines of way are found in a station, and when a sufficient amount of time and labour are at disposal. With many lines of way, on the contrary, as is the case in large stations, it is impossible to take up all the rails, and it must then suffice to remove the through lines, or, at all events, the switch-rails and crossings.

It will, however, be in few cases possible to transport all the rails and sleepers removed; but, at any rate, all switch-rails and crossings must be placed out of the reach of the enemy.

As the removal of the permanent way is effected in stations as on the open line (§ 8), only that of switches and crossings will be now described.

(*a*) *Switches or points.*—For these, the work of demolition consists in:—

1. The removal of the switch tongues, after undoing the fastenings.

After this is effected, and the key of the connecting rod is removed, the tongues may be lifted up, together with the point rods.

2. Removal of the stock rails after taking out the screws *a*

(*Plate VII., fig.* 2), the hook-nails, and detaching the fish-plates on the rails at the point of junction.

3. Removal of the arrangement for altering the points, after screwing off the lever or crank arrangement.

4. Raising up the sleeper under the points by the aid of levers or crowbars.

5. Carrying and loading of all material.

If there is not sufficient time to carry away everything, the switch tongues, at least, must be taken.

The removal of a switch may be accomplished by 16 men provided with 6 screw spanners and 12 levers, in 10, or at the most, 15 minutes.

It will, however, be advantageous to remove not only the actual switches, but also the curved rails of the points and, where possible, the rails of the main line as well.

(*b*) *Crossings.*—As the individual parts of crossings, namely tongues, wing-rails, and guard-rails, are usually secured in exactly the same way as the main rails, the principles laid down in § 8 hold good for their removal. The tongues of chilled iron or cast steel are raised up after the removal of the nails, together with the wing-rails belonging thereto, by means of crowbars. Tongues and wing-rails should not be left, as a rule, for the adversary, but should, if possible, be always taken away.

(*c*) *Turn-tables.*—No particular importance is attached to the destruction of turn-tables, as they very seldom serve for the connection of main or through lines, but are only employed on sidings to give a means of access to the rails of engine houses, workshops, &c. Still, should it be desired to render turn-tables unserviceable for a short time, it may be done by removing the central pivot and the turn-table rails. To render it useless for a considerable time could only be effected by blowing up the platform.

(*d*) *Travelling platforms or traversers* may, like the turn-tables, be left untouched, and for the same reasons. Should it be necessary, however, to include them in the demolition, they may be rendered unserviceable by removing the rails on them, and the wheels on which they run, by destroying the girders of the traverser; and, in the case of sunken traversers, by blowing in the sides of the traverser-pit as well.

§ 11.

Water Supply.

The rendering useless of the arrangements connected with water supply deprives an adversary of an indispensable help in the

working of a line, and compels him to occupy much time in their restoration. Endeavours must, therefore, be made to destroy as thoroughly as possible all arrangements for the supply of water, particularly as this may be done very simply and quickly.

In the first place, all contrivances connected with the feeding of the water-tanks must be demolished.

The pipes, and especially bends and angle pieces, must be removed, and, when possible, taken away altogether. The piston-rods and pistons must be taken out of the pumps, and the rising pipes screwed off. If there is not sufficient time for this, the pipes must have wedges driven into them. In the case of a steam-pump, the transmission arrangement, as well as the piston, must be taken out of the cylinder. When the filling of the water-tanks has been made impossible, the arrangements for watering the engines must be partially demolished by removing the pipes as before mentioned; in this case this is very easily effected, as leather hose is very often used. The cocks, when all the above-named work has been carried out, may be left intact, for if the feeding of the water-tanks is impossible, and the main to the cocks is interrupted, these will of course not act.

The water-tanks need not be destroyed, for not only are they very easily repaired, but also their demolition can only be effected by blowing up; and by so doing the buildings in their neighbourhood suffer and damage is caused, which the small delay thus occasioned would not justify.

§ 12.

Stations and other Buildings and Fittings.

Buildings are convenient, it is true, for carrying on traffic, but they are not indispensable; the possibility of communication exists without them, and the adversary by their demolition would be prevented from making use of the railway only for so long a time as the removal of the *débris* and rubbish lying upon the line of way would require. The time and labour expended in such a demolition might probably be infinitely better employed in some other way.

Consequently it should be established as a principle, that buildings should only be demolished or blown up, when by so doing other military advantages are gained in addition to the mere interruption of the railway traffic.

In all cases, however, the movable fittings which are found in the buildings, and according to which the latter are designated either as workshops, stores, or fitting shops, should be removed. The different workshop fittings must, therefore, be taken away altogether, and if

this is not possible, they must be rendered useless by the removal of important parts. Stationary engines should be made unserviceable by taking out the piston and removing the transmission arrangements; telegraphic apparatus and batteries must be removed. Fuel, permanent way material, and reserve plant, as well as raw material, should be taken away if possible; if not, they must be destroyed or rendered useless. The smaller tools should be taken out of the workshops; but it must never be thought that by this alone the workshops will be made useless, for in most cases an enemy would be well provided with such implements.

Wells may be rendered useless by blowing in their sides, or by filling up; large and important ramps, especially at good stations, should be blown up; on the other hand, small ramps, platforms, and portable weighing machines may in most cases be left intact.

§ 13.

Rolling Stock.

The enemy may be deprived of the use of the rolling stock, either by withdrawing it from the probable range of his operation, or by rendering the locomotives and carriages unserviceable to an extent corresponding with the object in view. Whenever possible, the former plan should be adopted, provided the rolling stock can be spared. Care must be taken beforehand that at the stations appointed to receive the locomotives and carriages, there is a sufficient length of sidings; if necessary, rails must be temporarily laid down along the side of the railway, or even on the roads, to supply any deficiency.

But if it is altogether impossible to remove the rolling stock, the time at disposal should be employed in rendering it useless, at least temporarily.

Of the many methods by which this is attainable, only those will here be mentioned which are easily carried out.

Locomotives may be rendered useless in the following ways:—

(*a*) *By screwing off the injector.*—But if an engine has, in addition to an injector, an ordinary feed pump, or, as is the case with engines of old construction, only a feed pump, the valve in the feed-head must be taken away. For this purpose, the screws *s* (*Plate VIII., fig.* 2) on the cap *d* must first be undone, the cap *d* removed, and then the ball valve inside lifted up by pulleys. By this means the water that is in the boiler will flow back, and it will be impossible to use the locomotive until the ball valve is replaced.

(*b*) *By screwing off a steam dome.*—With engines of recent con-

struction, which very frequently have steam domes made to screw off, this is the simplest and surest means of rendering an engine unserviceable, and it has the advantage that the engine can be got ready for use again almost immediately.

(*c*) *By removing the connecting rods on each side of the engine.*—To do this the wedge *z* (*Plate VIII., figs. 4 to 6*) must be removed, and the horizontal bolt *a*, fastening the connecting rod to the cross-head, must be struck out; the connecting rod can then be easily removed.*

Coupling rods may also be removed in this way.

(*d*) *By removing the piston.*—To do this, the screws on the front cap of the steam cylinder are unfastened, the cap *d* (*Plate VIII., figs. 3 and 4*) is drawn off, and the most oblique wedge, which effects the connection of the piston-rod with the cross-head, is knocked out; the whole piston can then be drawn out of the cylinder. To facilitate this, it is advisable in the first place to loosen the stuffing-box *h* a little at the back.

The removal of the piston can be almost momentarily effected with a heated boiler, if the connection between the piston-rod and the cross-head is severed by taking out the wedge, and steam is then let in through the openings at the back of the cylinder. The thus loosened piston then presses the cap of the cylinder forcibly out. As in this proceeding the cylinder is generally shattered, it must only be done when no particular regard has to be paid to the saving of material.

(*e*) *By removing the safety-valve.*—The valve becomes useless if either the bar *a* (*Plate VIII., fig. 1*), the safety lever *f*, or the spring balance *f'* is removed. If there is not enough time to remove these individual parts, a blow with a hammer on the cap is sufficient to destroy the whole system.

The most essential parts of the sub-structure of carriages are the axles and wheels. By removing, and at once carrying away the latter, the unserviceableness of the carriages is most completely attained. As this is, however, in very few cases practicable, it appears more advisable to be content with the removal of the springs. For if these are taken away, the body of the carriage falls with its underside directly upon the wheels, and the moving of the carriage is prevented until the springs are restored. To do it, the screw nuts *m* (*Plate VIII., fig. 7*) are removed from the axle-bearers *a*, the bolts or screws *b* are taken out from the bearers of the spring *f*, and the latter is withdrawn. To facilitate the work, the longitudinal bearers of the body of the

* According to experiments made, the removal of a feed-head valve or a connecting rod by two men, provided with a hammer and screw-spanner, lasted, on an average, 3 minutes.

truck may be supported beforehand by means of screw-jacks; after the removal of the springs, the body is let down on to the wheels.

Carriages with wooden frames may be rendered permanently useless by sawing the frames through in one or several places; before doing this the sheet iron, with which the sides of the frames are usually covered, must be cut through. This, however, occupies much time, and the method given when speaking of tunnels (§ 2), of running carriages off the rails, is preferable, especially when many trucks have to be destroyed; by this means, simultaneously with the destruction of the trucks, a barricade is formed, which is chiefly of advantage in cuttings and stations.

§ 14.

Signals.

The poles, levers, and arms of the visual signals, the shunting and stopping signals, as well as all hand signals, must be altogether removed. The wire of the electric signals must be destroyed by cutting and twisting, and by removing some poles. If time permits, the wires should be taken down and rolled up properly. All apparatus and batteries must be taken away.

PART II.

RESTORATION OF RAILWAYS WHICH HAVE BEEN DESTROYED OR RENDERED UNSERVICEABLE.

§ 15.

Introductory Remarks.

In restoring railways which have been destroyed or rendered unserviceable, all constructions and erections are of a temporary character, as it is only intended to make a line fit for traffic with the smallest consumption of time and by the simplest means, for the period that it will probably be required.

The quality of the materials, the nature of the constructions, and their execution, are, in such restorations, only to be so far taken into account as to secure the safe carrying on of the traffic; at the same time all regard for appearance is quite omitted, and convenience is only taken into the question when, by doing so, no greater consumption of time, labour, or materials will be entailed.

There is often, consequently, a great difference between the design and execution of temporary constructions of this kind in the field, and those of permanent constructions erected in time of peace. For example, with permanent constructions, while the permanent way is being prepared, the greatest care is taken to ensure easy running, and to place the sleepers as far apart as possible, and so on; but with field railways, on the other hand, any description of permanent way which leaves no cause for fearing that the trains are likely to run off the rails, is considered to answer all purposes.

In the following pages it will be shown how portions of a railway which have been destroyed or rendered useless may be restored for use in the field; and how far, in such restorations, the method of executing ordinary permanent constructions may be departed from without affecting the safety of the traffic.

CHAPTER I.

Main Works.

§ 16.

Embankments, Cuttings, Tunnels.

Although embankments are not often destroyed, on account of the great consumption of time and labour necessary, their restoration is nevertheless taken into consideration here, as it is quite possible they may sometimes be found demolished.

Filling up, ramming down, and levelling the deficient embankment now appear to be undoubtedly the simplest methods of restoration, and are, when the length and depth to be filled in are not considerable, the most advantageous; but much depends upon local circumstances.

Slight demolitions of embankments are but seldom met with, for as a rule, if an adversary finds himself compelled to destroy an embankment, he will do all he can to create a very considerable obstacle. According as its extent increases so does the restoration by filling up occupy a longer time than that by forming a temporary wooden construction; it is therefore sometimes advantageous to employ the latter method. In cuttings which have been blocked, one line of rails must first be cleared and then the other. If the sides have been blown in, a careful examination must be made, and all movable rubbish removed, so that passing trains may not be endangered by its falling.

Tunnels which have been blocked must be cleared; if, however, they have been destroyed by gunpowder, not only the extent of the explosion, but also the geological nature of the ground above and around, must be narrowly investigated, and the construction of the walls examined. By this means it can be decided whether a simple clearance of the *débris* is sufficient (as, for example, in tunnels through rock without revetements); or whether, and to what extent, it may be necessary to repair the injured walls. Various cases may be met with; they are always, without exception, dangerous, and require excessive precaution. A temporary wooden lining should only be constructed when the existing revetment is very weak ($1\frac{1}{2}$ or 2 feet thick). The uprights, struts, and transoms employed for this purpose must follow the rectilinear normal section of the open line in the clear, and the sheeting must be placed on the outside. Strong revetements show that a considerable side-thrust had to be provided against, and it would in this case be extremely dangerous to undertake a restoration with the limited means of a Field Railway Division. In a case like this, and when an elaborate tunnel-vaulting is damaged at the top, not a moment should be wasted in the

endeavour to reconstruct the tunnel temporarily, but, if possible, a temporary line should be laid down, and the tunnel avoided altogether.*

If, however, the hill through which the tunnel passes, is not high, the whole superincumbent mass resting on the destroyed tunnel may be cut away to the necessary slope, and thus a cutting with very high sides may be formed. In 1870, the third German Field Railway Division rendered the tunnel of Armentier, which was blown in for a length of 500 feet, passable in this way; no timber to form framing was to be had, and the hill above the tunnel only had a height of 100 feet. Here, the work was begun at the top, the necessary slopes were given to the cutting, and the sides were partially reveted, for which purpose 80,000 bricks were required.

§ 17.

Temporary Wooden Constructions in General.

Bridges, viaducts, and, to a certain extent also, embankments which have been destroyed, can in time of war, when rapidity of execution is of the first importance, only be replaced by temporary wooden constructions. Extreme simplicity, combined with perfect security, should characterise such a field-construction.

In executing such works, the formulæ founded on experiments made on different railways, and the principles generally laid down in the building of permanent wooden bridges, may be applied in the case of temporary wooden constructions.

As it is supposed that the reader is familiar with the principles of bridge construction, as well as with the technical execution of details, only those matters will be treated of in the following pages which relate

* The attempt of the second Field Railway Division to reconstruct the tunnel at Nanteuil, on the railway from Nancy to Paris, which was blown in during the Franco-German War of 1870–1, forms a very instructive case in point.

This tunnel, about 1,000 yards in length, was blown in by the French by charges loaded in the side walls, so that not only was the masonry of the vaulting and side-walls completely destroyed for a length of about 100 feet, but also the hill above (about 250 feet high) was loosened, and some portions fell into the tunnel, while others slipped over it. As the rebuilding of the destroyed portion could not be thought of, on account of the great consumption of time and insufficient means, the construction of a temporary line in a gallery lined with woodwork was set about. *Plate IX., figs. 1 to 6* show the successive steps of the work. When, at the end of 4 weeks, this was almost completed, considerable displacements were caused by the pressure of layers of the hill, which was of the tertiary formation; various beams of the strong wooden framing were displaced and broken, until at last the complete collapse of the nearly restored portion followed. Hereupon a circuit of the tunnel by means of a field railway was undertaken, and, with the help of 1,000 workmen, was completed in 23 days.

to peculiarities in the construction of railway-bridges in the field. With railway-bridges generally, greater loads comparatively have to be allowed for than with road-bridges; but with temporary field railway-bridges the carrying out of such a construction as will best suit the particular circumstances is all that has to be sought after; for not all constructions, which are executed in time of peace, are applicable for constructions in the field; since, for example, for the formation of groups of piles, trussed and suspended bridges combined, lattice-bridges, &c., the time at disposal is in most cases insufficient. Bridges on piles, trestle-bridges, and, in extreme cases, trusses, may be pointed out as the simplest constructions in field railway-bridging.

In the execution of a structure which is only intended to last during a campaign, there is not the same demand for solidity and durability as in a permanent structure. Consequently, materials of smaller dimentions and of inferior quality will suffice, all complicated joints will be avoided, and cramps, screw-bolts, &c., will be employed instead. The dimensions which are adopted need only be those which will ensure that security which is indispensable. Finally, it must not be overlooked, that a project for the construction of works in the field is not so much dependent on the dimensions (as in the case of permanent works) and on the quality of the materials as on the materials at hand, or those which can be procured in the neighbourhood, which have to be made use of.

Taking the above facts into consideration, and in order, at the same time, to give some guide for cases which frequently occur in war, the two following sections contain:—

Data which are generally absolutely necessary for the calculation of the strength of wooden railway-bridges; and

Rules for the formation of temporary structures in war, as well as some examples, which, with the aid of standard designs, may be adapted to various special cases.

§ 18.

Data for Calculation of Strength.

The calculation of the strength of the bridge must embrace equally that of its superstructure and that of its supports.

The superstructure of a railway-bridge consists of the rails, sleepers, and bearers. The weight of the rails and sleepers may be disregarded, for on every foot run of the length there is only a load of 66 lbs.;* therefore, only calculations as to the strength of the bearers and supports are given.

* As the average length of a locomotive of 25 feet covers about 8 sleepers and

(*a*) *Calculation of the bearers.*—Only those bearers will now be spoken of which serve for the direct support of the rails. The dimensions of these bearers must correspond with the greatest probable load which is caused by the occupation of the whole length of the bridge with locomotives. If the average weight of a locomotive is taken at 600 cwt. and its length at 25 feet, there will be, supposing the load uniformly distributed, a load of 25 cwt. per foot run of the permanent way, and, therefore, $12\frac{1}{2}$ cwt. per foot run of a single rail.* This load (Q) would be, therefore, for a certain given length L, equal to 12·5 L, per foot run.

Breadth of opening in Feet.	6	12	18	24	30	36	42	48	54	60
Factor by which load is to be multiplied † to reduce it to equivalent distributed load.	2·5	2·2	1·96	1·8	1·65	1·4	1·32	1·24	1·12	1

This assumption, however, only applies in the case of long-span bridges; with short-span bridges to obtain the load on the bridge, those wheel-pressures, which occur at particular points of the bearers according to the position of the locomotive, must be calculated. It is, however, possible to calculate a uniformly distributed load, which taxes the strength of the bearers similarly to the concentrated wheel-pressures referred to; and here generally, Q = 12·5 L C; the co-efficient

$1\frac{1}{8}$ rail-lengths (taking the longest rails used in Austria), the weight of this length of permanent way amounts to:—

8 sleepers at 2 cwt. each	16 cwt.
$1\frac{1}{8}$ rail-lengths of 21′ each, at the rate of 4 cwt. per pair of rails	10 cwt.
Total	26 cwt.

Of these 26 cwt., 13 cwt. are borne on each rail, or about 66 lbs. per foot run. This is so small, compared with the weight of the locomotive, that that of the permanent way may be left entirely out of consideration.

* The Southern Railway Company in their calculations put the weight of an ordinary locomotive and tender at 30,000 kilog. = 600 cwt. If, therefore, as above, the whole length of the bridge loaded with locomotives of 600 cwt. be calculated for, this appears quite sufficient.

† The factors given above are calculated according to loads experimented with in the construction of the bridges on the Empress Elizabeth's Western Railway. Several engineers have calculated the factors for the case under consideration, which differ only very slightly from each other and from the table above.

C decreases with an increasing length of bridge, and for a length of 60 feet and upwards is taken as unity.

For spans which are less than 6 feet, the bearer has to be calculated for the pressure Q_1, which the heaviest locomotive exerts when standing at its centre.

The following formulæ may be applied for the calculation of the dimensions of a bearer:—

1. For the rectangular section: with bearers 6 feet long and over,

$$\frac{Ql}{8} = \left\{\frac{rbh^2}{6}\right\}n,$$

with bearers under 6 feet in length,

$$\frac{Q_1 l}{4} = \left\{\frac{rbh^2}{6}\right\}n.$$

In these formulæ, $\frac{Ql}{8}$ and $\frac{Q_1 l}{4}$ denote the greatest moments, i.e. the sum of the statical moments of the exterior forces acting on one half-bearer; l, b, h, are expressed in inches, and $\left\{\frac{rbh^2}{6}\right\}n$ denotes the sum of the statical moments of the resisting forces of the aforesaid bearer; or, more shortly, the 'admissible moment of resistance' (called by Rebhann, *das Tragmoment*, the bearing moment). Further, r expresses the highest admissible pressure in cwts. (Vienna) per square inch, and n the number of bearers supporting one rail; b denotes the breadth, and h the height of the bearers.

2. For bearers formed of circular logs, flattened on two sides, and whose section resembles a rectangle, to which two parabolic segments have been added, the formula

$$\frac{Ql}{8} = \frac{rh^2}{30}n\,\{2b+3b_1\}$$

is used; where b_1 denotes the breadth at top and bottom, and b the breadth at the centre.

3. For combined bearers:

$$\frac{Ql}{8} = \left\{\frac{r_1 hb^2}{6}\right\}n.$$

Here, r denotes the greatest admissible load on combined baulks, which becomes less according as the rigidity or stiffness of the connections decreases, that is, when screws without teeth and dowels are used.

$$\left.\begin{aligned} r_1 &= \tfrac{2}{3}\,r, \text{ if two} \\ r_1 &= \tfrac{1}{2}\,r, \text{ if three} \end{aligned}\right\} \text{ bearers are combined.}$$

When the baulks are dovetailed,

$$r_1 = \tfrac{3}{4}\, r.$$

Having the preceding formulæ, there can be no difficulty in finding the strength of the bearers, their dimensions being fixed, or, in finding the necessary dimensions, the load being known, as soon as r, the admissible working load, is known. In determining the dimensions unmerically, the experiments which have been made in railway-construction, and existing rules, as well as constructions which have been actually executed and tested, may be taken as guides.

The Royal and Imperial private Southern Railway Company has issued fixed rules for the construction of their temporary structures, in which the admissible load is laid down at 120 kilog. per square centimetre, equal to 14·88 cwt. per square inch, or, for round timber, 15 cwt. per square inch.*

On the Emperor Ferdinand's Northern Railway no fixed formulæ have been laid down, but standard designs for different spans have been planned. *Plate IX., figs. 7 to* 16, and *Plate X., fig.* 1, show temporary constructions founded on these designs. A calculation made according to what has been said above, and with the help of the formulæ, gave as admissible load from 9 to 11 cwt. per square inch.

In the same way, the greatest load on some of the temporary structures on the Charles Louis Railway was found to be 15 cwt. per square inch.† (*Plate X., figs.* 2 *to* 4, and *Plate XI., fig.* 1.)

If now the temporary arrangements mentioned be taken as a basis for the determination of the admissible load on the square inch, r is found to vary between 9 cwt. and 15 cwt. If the load $r=9$ be taken, in every case the customary limit in the case of permanent bridges is obtained; with thoroughly sound timber and rigid connection, r may be taken at 15 cwt., as the extreme limit.

(*b*) *Calculation of the supports.*—These will consist only of piles, trestles, and simple trussed frames.

For the calculation of the strength of the piles or vertical supports, the very simple experimental rules given in Weiss' *Art of Construction* may be made use of. According to these, there may generally be taken, for vertical timbers, irrespective of their nature, a load of 2 Vienna cwt. on each square inch, provided the height does not exceed thirty diameters. As the height diminishes, the strength increases, so that each square inch of section may be taken to carry,

* To convert kilogs. per square centimetre into Vienna cwt. per square inch, multiply by 0·124.

† In this determination of the admissible load, the supports were neglected, and the clear length *e f* taken. (*Plate IX., figs.* 7 *to* 16, *Plate X., figs.* 1 *to* 4, and *Plate XI., fig.* 1.)

with a height 25 times the diameter, 3 cwt.

„	20	„	„	4	„
„	15	„	„	5	„
„	10	„	„	6	„

The number of piles or vertical supports which must be used in a simple or complete pile-work, or in a trestle-bridge, is governed partly by the above rules, partly by the load on the piles, and partly by constructional considerations.

It may generally be taken that 3″ vertical timbers $\times 2'' \times 12''$ and 2 struts (which are not taken into account), fixed at a height of 20 feet, are sufficient for one group of piles, if the bridge is only designed to carry one line of rails. The temporary constructions shown in *Plate X., figs.* 1 *to* 4, and *Plate XI., fig.* 1, give more than the necessary safety in this case. Trussed frames are generally only admissible for small spans, when there is plenty of height, and when the footings are good; under these circumstances, they are easily available for the strengthening of pile-constructions. In calculating the strength of the parts of the trussed frame (struts and straining-beams), the load Q which acts at the point of support, and the angle α (*Plate IX., fig.* 15), must, first of all, be ascertained; then the pressure on the strut $Q_1 = \frac{Q}{\cos \alpha}$, and that on the straining beam $Q_2 = Q \tan \alpha$.

In calculating the section necessary, the proceeding is the same as in the case of struts and columns which sustain a thrust in the direction of the axis. For example, for the strut Q_1 it is equal to $r_1\, bh$, where b is the breadth, and h the height of the section, and it is assumed that b is equal to or less than h.

In order to find r, the formula

$$r_1 = \frac{r}{1 + 0{\cdot}00576(\frac{1}{b})^2}$$

is used, where, according to the rules for thrusts along struts or compression bars, r is only to be taken as 5·2 cwt.

§ 19.

Rules and their Employment in Special Cases.

As, in the foregoing paragraphs, the construction and calculation of temporary wooden structures erected during a campaign is only generally treated of, it appears advisable to thoroughly consider from a constructive point of view a few cases, which would probably be most likely to occur.

In *Plates IX., figs. 7 to 16*, and *X., fig. 1*, several constructions with spans from 6 feet to 60 feet are given, which may serve as guides; in *Plates VI., figs. 6 and 7a, X., figs. 2 to 4*, and *XI., figs. 1 to 3*, some examples are shown.

If, in a given case, the material which is used in the construction of the standard designs can be procured without loss of time, the execution of the work can be forthwith proceeded with, in accordance with the same. If, however, timber of less dimensions than those given is only at disposal, the length of the girders and their section must be brought into a proper relation with the number of piers or supports; and, similarly, the height of the piers must be varied with the depth of the obstacle, &c., in each particular case. A calculation which thus harmonises local circumstances with the materials at hand, and which must be based upon the principles enunciated in §§ 17 and 18, will always show clearly what standard designs, or combinations of the same, best answer the required purpose. A few examples will show how the given designs may be made use of in the case of destroyed bridges, as regards the material of which they are constructed.

(*a*) *Stone bridges.*—If the piers are only partially damaged by gunpowder, they are still available as foundations for trestles. In the example given in *Plate X., fig. 4*, trestles* in two stages have been erected and strengthened by trussed frames. The clear length $ef = 15$ feet. One rail-length is supported by $1\frac{1}{2}$ bearers; one bearer is formed of two baulks, 13″ by 14″, bolted together. The superimposed weight is therefore similar to that in the construction of the standard design, *Plate IX., fig. 16*; the construction is thus quite safe.

In the case of piers entirely useless (*Plate XI., fig. 1b*), or of arches quite blown down (*Plate XI., fig. 1a*), when the erection of trestles is impossible, piles must be driven, as shown by the respective figures.

* In the War of 1870-71, the German Field Railway Divisions very frequently made use of trestles in the restoration of stone bridges. The restoration of the demolished bridge over the Marne at Chalifert is shown in *Plate XI., fig. 2*. The explosion had caused a gap of 86 feet; the scattered masonry had filled up the opening to such an extent, that the course of the stream was hindered; by stone-packing, with the interstices filled up with rubbish, a dam, reaching to 16 feet above the water-level, was formed, and there then remained a height of about 30 feet for the construction. There were 11 trestles 8 feet 4 inches apart from centre to centre. The cross-bracings were secured with iron-cramps, while strong nails only were used with the longitudinal bracings. The corbel pieces were connected with the bearers by 2 screw-bolts. As the two sides of the arch unharmed by the explosion were not sufficiently safe to allow the bearers to rest directly upon them, it was necessary to arrange another trestle on the masonry. In a similar manner the temporary bridge of Meaux, at Isles, was constructed for about 84 feet.

Without allowing for the supports *cd*, the clear length *ef* = 21 feet 6 inches. A rail-length is supported by 1½ bearers; a bearer is formed by two baulks, 13″ by 14″, bolted together. The superimposed weight is therefore less than in the construction of the standard design, *Plate IX., fig.* 15.

(*b*) *Bridges of Wood.*—If the piles are not completely destroyed, and are still fit to be used as supports, they must be cut off level, and provided with a cap-sill, on which the new pier may rest. *Plate IX., figs.* 12, 13, *and* 14, and *Plate X., fig.* 1, would serve to explain any constructive details if it is contemplated to make use of the pile foundations as a support for the timbering of the bridge. If, however, the piles are destroyed below water-level, new ones will have to be driven.

If the bed of the opening is dry, and sound stumps of the piles are left which can be cut off level, the formation of the pier may be also effected in the way previously described.*

If the bridge rests on stone piers or iron pile-work, and the superstructure only is destroyed, as many intermediate piers as are necessary must be formed corresponding to the dimensions of the bearers, in addition to the restoration of the superstructure.

If only individual parts of the superstructure are damaged (sawn through, for example), they must either be replaced or supported underneath, according to the nature of the construction.

(*c*) *Iron Bridges.*—If the rails and sleepers have been removed, their places must be supplied by new ones when they are to be had. Deficient iron girders can only be replaced by wooden ones.

If the construction, in the case of suspension bridges, has been weakened by the removal of bolts, king-posts, &c., the missing parts must be supplied as far as possible from the materials at hand. Neville bridges, from which the wooden cross-girders have been removed, may be restored by laying temporary cross-girders in the chairs (*f*), which are made on purpose to receive them (*Plate VI., figs.* 4 *and* 5).

* A method which was adopted in the campaign of 1866, in the temporary restoration of the Altenmarkt Bridge, deserves mention here. The piles of the existing wooden bridge had been burnt down to stumps about 1 foot high. On both sides of the stumps transoms were placed, and secured by means of bolts passed through them. In the opening thus formed, and terminated by the stumps, the vertical timbers were fixed, and the bolts drawn close, by which the cutting off of the ends of the stumps and the cogging of the capping-piece were avoided. The remainder of the work was carried out in the ordinary way. In a similar way, in the campaign of 1870–71, the wooden bridge over the Maine at Châlons, which had been burnt by the French by means of petroleum, was restored by a German Railway Division (composed of French railway officials, and soldiers under the engineer Glaser); the vertical supports of the new bridge were bolted on to the existing foundation-piling *a* (*Plate XI., fig.* 3), at the water line.

Schiffkorn bridges, from which either all or only some iron cross-girders have been removed, may be again made passable if, instead of these girders, timber trusses are fixed, as follows* :—On the bottom boom transoms (a'), 16 feet long and 8 inches square, are laid as close as possible to the joints (*Plate VI., figs. 6 and 7a*). To effect this, they may be diminished at the ends. On these transoms there comes a timber truss 8″ square. To stiffen the bearers and framing, four longitudinal baulks (b) are halved into the transoms, and struts (c) are fixed. The distance apart of the trusses depends on the strength of the longitudinal bearers ; it is, as a rule, 3 feet (i.e. at the same distance apart as the joints), but with bearers 13″ by 14″ it may be 6 feet (i.e. at every other joint).

The calculation given in the note† shows that this construction is

* In the campaign of 1866 the Prussians restored Schiffkorn bridges, which had been destroyed on the Kralup-Turnau Railway, in the following way :—Platforms about 3 feet broad and 15 feet long were formed of planks laid cross-wise over each other upon a plank framing; these were nailed with long nails, two to each cross-bearer ; the latter were grasped by the wrought-iron suspension braces of the booms ; on these the longitudinal bearers carrying the rails were laid, after wooden bars had been arranged cross-wise to give stiffness in the direction of the length. The platforms were wedged up against the bottom boom, in order to prevent a lateral thrust upon the cast-iron cross-braces.

† The pressure Q of a wheel (of a 6-wheeled engine of 600 cwt.) is 100 cwt.
Taking, as the most unfavourable case, α equal to 40° ;

Pressure along the strut $\frac{Q_1}{\cos \alpha} = \frac{100}{0{\cdot}7660} = 132$ cwt. ;

Pressure along the straining beam $Q_1 \tan \alpha = 100\ (0{\cdot}8391) = 189$ cwt.
The safe load of the struts should be $r_1\ b^2 = 132$ cwt.
Whence,

$$r_1 = \frac{r}{1 + 0{\cdot}00576 \left(\frac{l}{b}\right)^2} = 4{\cdot}3 \text{ cwt.}$$

Therefore,

$r_1\ b^2 = 4{\cdot}3 \times 64 = 275{\cdot}3$ cwt., or more than twice what is required.

The safe load of the straining-beam should be equal to 189 cwt. ; but it is

$$r_1 = \frac{5{\cdot}2}{1 + 0{\cdot}00576 \left(\frac{42}{8}\right)^2} = 4{\cdot}4 \text{ cwt.} ;$$

consequently $r_1\ b^2 = 281$ cwt., or more than sufficient.

Longitudinal Sleepers.

In a clear length of 3 feet, Q = 93 cwt.

The safe load of a sleeper is $\frac{2rbh^2}{31} = 96$ cwt.

With longitudinal sleepers of 13″ × 14″ timber, for a clear length of 6′ Q = 187·5 cwt., and the safe load of such a sleeper is

$$\frac{2rbh^2}{31} = 212 \text{ cwt.}$$

sufficiently secure. Cases may, however, occur in which the restoration of piers is attained more quickly inside the lattice-work which may be left standing (*Plate XI., fig.* 1*b*); when, for example, all the transoms of a bay have been removed the bed of the obstacle is dry, &c.

Iron bridges which have been destroyed by blowing down, and in which a partial loosening, sinking, or straining of the iron-work has been effected, must be replaced by a temporary construction, which, if possible, should be formed exactly on the axis of the existing bridge; or, if this is impracticable on account of the time which would be taken up in clearing away the damaged ironwork, a new axis must be taken. In the latter case, endeavours should be made to effect the junction with the open line by an arc of the greatest possible radius. For this purpose, either the old embankments must be widened by bridge-like constructions, or new embankments must be branched off on a curve.

The time which each of the foregoing restorations would require depends on their extent, the means at command, and on local circumstances. In general, it may be assumed that the restoration of pile-work of the simplest construction, together with the two adjoining bays, may be accomplished in from 10 to 12 hours, the materials being at hand, and other circumstances favourable.

CHAPTER II.

Permanent Way.

§ 20.

General Remarks.

The extent of the restoration of the permanent way must depend upon the time for which it will probably be required. The time, labour and materials at disposal will always decide in how far the work in the field can answer this requirement. But as it is most important to lay down the limits of simplicity of construction (which the temporary construction should not go beyond in time of war) without incurring any risk, each individual element of the permanent way will be treated of in the following pages with this view.

On the formation level only the under ballast *u* (*Plate XII., fig.* 1*b*) is necessary; all the arrangements for drainage, as well as the intermediate packing, may be omitted.

The description of sleepers depends on the material at hand. If there is any choice, however, the preference should be given to wooden transverse sleepers; if it is found necessary to make them, they may be given a trapezium-shaped section, and they will answer every

purpose, their upper surfaces being trimmed, or merely having rests cut out for the rails.

Sleepers of different heights are no drawback, for the difference of level may be counteracted by the ballast. To facilitate the work, transverse sleepers may be laid 3 feet apart throughout (*Plate XII., fig.* 1); it is sufficient to have the sleepers (*a*) under the rail-joints, and one intermediate sleeper, the places of the others being taken by blocks of wood, the length of each of which is about one-third that of an ordinary transverse sleeper. As, however, this arrangement takes time, on account of the difficulty in laying and under-packing &c., it should only be adopted when the supply of timber is deficient. Longitudinal sleepers (*d*) should be used when possible instead (*Plate XII., figs.* 2 *and* 2*a*); this is most simply effected by using cross-sleepers (*e*), laid under the joints, and having grooves from 3″ to 4″ deep, to receive the longitudinal sleepers. These grooves are absolutely necessary.

The securing of the rails can only be simplified in the case of flat-bottomed ones; by doing away with the bed-plates, by reducing the fish-plate connections from 4 to 2 screw-bolts, and by diminishing the number of nails by one-half. If no fish-plates are to be had, the ordinary number of nails must be retained, and in this case joint-plates (*t*) are desirable (*Plate XII., fig.* 1).

This also applies when block-sleepers are used.

§ 21.

Laying the Permanent Way.

In the following pages, the proceeding which must be adopted when transverse sleepers are used will be more particularly described, as longitudinal sleepers are seldom found to occur, and the work in both cases is much the same.

(*a*) *With flat-bottomed* (*Vignoles'*) *rails*, the work to be done consists in:—

I. Levelling the ballast, laying out the centre line, and running levels.

II. Laying the transverse sleepers; in doing this, it is advantageous to use a lath with the distance apart of the sleepers marked upon it. At the same time, any bed-plates at hand might be laid down.

III. Laying the rails. As soon as about 24 sleepers have been placed, the rails are laid upon them as straight as possible, and separated by about the proper distance. When this has been done for about 3 rail-lengths, there begins,

IV. The screwing on of the fish-plates, for which 2 screw-bolts are used; the space between the rails at the joints, which, in permanent

work, differs according to the temperature, here may in all cases be fixed at a quarter of an inch. To maintain this distance, small plates of wood are inserted. When 3 rails have been provided with fish-plates, there follows,

V. The fastening down of one length of rail. To facilitate this work, the respective sleepers are pressed against the rails with the help of a crowbar. As soon as the first rail is fastened to the sleepers, there comes,

VI. The fixing of the gauge, as well as the fastening down of the opposite length of rail, which is secured in the same way as the first, except that a clip-gauge is used. In order to get the rails exactly parallel, it is necessary to lay the clip-gauge over each sleeper. The nailing down of both rails is now continued in this order, until about 150 feet of the permanent way has been laid down; then follows,

VII. The setting of the rails horizontally. This work is accelerated, if only the extreme points of the length of line laid down are made horizontal by means of plummets and cross-sights, and the level adjusted, the intermediate portions being simply corrected by eye. As soon as the whole of the contemplated line is completed, comes

VIII. The adjustment of the entire length, i.e. bringing the track exactly into its true direction. This is done by means of crowbars. Curves require a widening of gauge and raising of the rails, the amount being governed by the radius of the curve. But as this radius is not always known, it suffices to give on an average an increased width of gauge of 1 inch, and to raise the outer rail from 3 to 4 inches above the inner rail. The short rails, which, in permanent work, are employed in these cases, may be entirely dispensed with in temporary restorations, and rails of the ordinary length can be used and cut down to the required length, without inconvenience, whether the joints of both rails are radial or not.*

Level crossings are formed in the usual manner. Wooden blocks are laid inside the rails, and about 2 inches from them, and nailed to the sleepers.

(*b*) *With chair-rails.*—In this case, the work is carried out as follows:—

I. Levelling of the ballast, &c., and
II. Placing the transverse sleepers } as with Vignoles' rails.

III. Nailing down the chairs along one rail. As soon as the sleepers have been placed for about two rail-lengths, the chairs are secured along a single rail with only one nail.

* On an average the cutting of a rail takes 6 minutes.

IV. Laying down and keying up one rail. As soon as the chairs have been secured on one side for about 4 rail-lengths, the rails are placed in them, and keyed up. After this work is completed along the first rail, then begins,

V. The work along the opposite rail. The chairs are placed on the sleepers, the rails laid in the chairs, keyed up, and gauged, and each chair is fastened with 2 nails; after which the second nail may be driven for the corresponding chair on the opposite rail.

VI. Making the rails horizontal and level } As in the case of
VII. Bringing the line on to its proper axis } Vignoles' rails.

For curves and level crossings, what has been said under the head of Vignoles' rails is applicable in this case. If double chairs are to be had, they should be used for points.

(*c*) *With mixed rails, sleepers, &c.*—If the employment of mixed materials cannot be avoided, they must be suitably connected, and the difference in section at points of junction must be adjusted proportionately.

As soon as the permanent way has been laid in any one of the ways described, the line may be opened for traffic. The careful maintenance of the line (raising sunken sleepers, packing, tightening fish-plate screws, &c.) will vary in its necessity, according to the length of time occupied in restoration, for the quicker the work, the less solidly and securely will it have been executed in all its details.

§ 22.

Distribution of the Workmen, &c.

In a demolition, a division of workmen was taken to consist of 4 superintendents and 56 men; it now remains to show by examples how the same number of skilled workmen would be able to split up into parties in accord and with the detail of work given in the preceding paragraph, in order so to temporarily restore the permanent way, that no cessation of work occurs, and that the different parts of the work follow each other without interruption. It is assumed here that Vignoles' rails, with transverse sleepers, are used—for in all other cases the method of procedure is much the same—and that a sufficient number of labourers* is available for bringing up the materials. The workmen are distributed in the following manner:—

* For a division of workmen constituted as above, 46 labourers—30 for bringing up sleepers, and 16 for each rail—are, in most cases, sufficient.

No. of party.	Nature of work.	Number of		Tools.	Remarks.
		Superintendents.	Skilled workmen.		
I.	Levelling the ballast; laying out the axis of the line, and arranging the level.	1	6	Pickets, mallets, levels, plummets, cross-sights.	All the labourers, as well as all the working-parties are employed in levelling the ballast; for immediately on the completion of this work, all the rest may be begun.
II.	Laying the sleepers.	—	4	Graduated rods.	The labourers and workmen above named are employed as sleeper- and rail-bearers.
III.	Placing the rails.	—	4		
IV.	Screwing on the fish-plates.	—	8	8 screw-spanners, 8 hammers.	
V.	Boring and nailing for one rail.	—	8	4 drills, 4 mallets, 4 crowbars.	
VI.	Fixing the gauge; boring and nailing for the opposite rail.	1	10	4 drills, 4 mallets, 4 crowbars, 2 gauges.	
VII.	Making both rails horizontal.	1	8	2 levels, 2 plummets, 6 cross-sights, 4 crowbars, 4 cramp-irons.	
VIII.	Final adjustment of the whole line.	1	8	8 hand-spikes, 8 cramp-irons.	Assist No. VII. party, till their own work is ready for them.
	Total.	4	56		

In order to be able to judge approximately the capabilities of a working party of this description, the results arrived at during a change of the permanent way* on the Emperor Ferdinand's Northern Railway, are here given.

The portion of railway in question was about 820 feet long (38 rail-lengths, each 21 feet 6 inches), on which the 150 men employed effected the removal of the old permanent way, and the laying down of the new, within 5 hours.

Before any conclusion can be derived from this special and extraordinary performance, as to the laying down of a temporary line of railway, it must be taken into consideration, that before the commencement of work the packing ballast had been all removed, and that from each fish-plate, 2 bolts had been already taken out, and the new material distributed along the entire length; that further, after the completion of work, the ballast was not replaced, and the staff of workmen was very efficient.

Taking up the permanent way occupied about half an hour; there then remained 4½ hours for laying down the line; 150 men therefore laid 38 rail-lengths in this time; and consequently, under similar circumstances, 56 men would be able to accomplish this amount in about 12 hours, and a length of about 620 feet (29 rail-lengths, each 21 feet 6 inches), taken as in the demolition (§ 8) in 9 hours, supposing that the labourers necessary for bringing up the material were available, the ballasting were made level before the commencement of work, &c.

If this rate of work is compared with that given in § 8, it appears that the permanent way on an equal length of line, with the same number of workmen, takes 9 times longer to restore than to demolish.

If there is a larger number of skilled workmen at disposal, existing circumstances will decide whether the surplus should be employed for strengthening the various parties of the divisions, or whether they should be united into separate divisions. In the latter case, work might be commenced at several points simultaneously.

* Carried out at Krzezowice, 5th September 1868: the condition was that the line should be ready within 5 hours.

CHAPTER III.

Stations, Rolling Stock, Signals.

§ 23.

General Remarks.

Where the permanent way has been destroyed in a station, the restoration of one through line and of a siding, and of the line connecting them must be first undertaken. Additional lines are restored later, and only in so far as traffic and other circumstances may demand. The connection between main lines may be effected for a time by means of switches only, as turn-tables and travelling-platforms cannot be quickly restored when the machinery has been destroyed.

As the rails are laid in stations in the same way as on the open line, the restoration of switches only will be treated of in the following pages.

§ 24.

Points or Switches.

In temporary points, the movable rail is usually the only kind of switch employed, if the stock of ordinary switch arrangements is exhausted.

Before laying the points, they must be, in all cases, traced out.

(*a*) *Tracing.*—If AA^1 and BB^1 (*Plate XII., fig.* 3) are two parallel lines to be connected and the end of the tongue is to be at I, this tongue $b\ a\ c$ will be placed at I with the side $b\ a$ in the direction of the inside rail, and the side $c\ a$ produced till it cuts the other rail $o\ p$ in d; the length $a\ d$ is then laid off along $d\ f$.

This gives the extremity f of the tongue. Inside the angle $f\ d\ a$, the curve $a\ f$ is drawn by eye, and the inner curve $h\ i$ parallel to it; by this means, one switch rail is determined. To lay out the connecting line, the side $a\ c$ of the tongue is produced towards the line $B\,B^1$; and parallel to it a line is drawn from the point h till it cuts the stock rail at a^1. By this means, the second a^1 is obtained, after which the laying out of the second switch rail $a^1 f^1$ may be affected similarly to that of $a\ f$.

If the points to be laid out are for an ordinary siding, instead of for a cross-over line, the proceeding is exactly similar to the former, except that there is no tongue required at the second crossing-point a^1 (*Plate XII., fig* 3).

Supposing that the place at which the points are to be is at II, for example; then in order to find the crossing point at I, a proceeding similar to the first given is adopted. The given tongue is first of all placed at the point II with one branch in the direction of the rail $o\ p$,

the other branch is then produced till it cuts the rail *m n* in *x*; the distance *fx* is set off from *x* towards *a*, and this gives the crossing point *a*; the rest of the work is the same as in the first case.

If two similar tongues are not available, the simplest plan is, instead of using the second tongue, to lay down a movable rail D (*Plate XII., fig.* 5), which process will be fully described further on.

Finally, if no tongues are to be had, these must be replaced at the crossing points by movable rails. In order to lay down the switch, it is placed at an angle of 7° with the corresponding rail,* and the subsequent proceeding is as already described.

(*b*) *Method of procedure with ordinary materials.*—After laying out and tracing the points, the actual laying of them, as well as the placing of sleepers, is begun. The latter is commenced at those points at which support is absolutely necessary (*ex. gr.* tongue, crossing points, &c.), and so many intermediate sleepers are added as will bring their distance apart to 3 feet. At the point fixed by the tracing the tongue *a* (*Plate VII., figs.* 3 *and* 4) is now secured to the sleepers, and forms the starting point of the work; it is not finally fastened down until the line of rails has been placed in its exact position.

In order to obtain the proper position for the wing-rails, two straight laths, N and O (*Plate XII., fig.* 4), 2 inches wide, are laid crossing each other exactly at the point of the tongue, the wing-rails are then placed with their ends against the laths, and fastened down to the sleepers. Then the rails are laid with an increased width of gauge of 1 inch in the curve as far as *w* (*Plate VII., fig.* 3), the end of the points, so that the ends of all four rails fall together upon the centre of the sleeper *s*. The different rails must therefore be previously adjusted as regards length, or they must be cut; after which, the final fastening down and placing of the rails follow, as well as the fixing of the guard rails *c* c^1.

Simultaneously with the adjustment of the switch tongues, the laying of the points is carried on; it is done in the following order:—

I. Laying the sleepers *r* r^1 for the points. (*Plate VII., fig.* 3.)

II. Placing the stock rails *t* and *t*, and connecting them with the adjoining rails by means of fish-plates.

III. Pushing the switch-chairs under and screwing them to the stock rails and sleepers.

IV. Laying in and securing the tongues *z* and z^1.

V. Raising the sleepers supporting the points by means of crow-bars (which requires special attention), as well as the exact adjustment of these sleepers.

* The angle 7° corresponds to a radius of 620 feet; with this angle the breadth *a b* of the tongue, from out to out is 9½ inches. (*Plate XII., fig.* 6.)

VI. Fixing the connecting and point rods v^1 and v.

VII. Fixing the arrangements A for altering the position of the points.

Two superintendents and about 28 men are required, half for laying out the direction of the crossing, and half for the points. For carrying out the work, the same number of workmen is necessary.

(*c*) *Method of procedure for temporary work.*—The proceedings in this case are nearly the same as those given under (*b*). The same number of workmen is also requisite.

The ordinary constituent parts of a switch may be replaced by the following temporary arrangements.

Instead of the tongue a movable rail D (*Plate XII., fig.* 5) may be used. For this purpose, flat-bottomed rails may be used, or rails at least 9 feet in length. The movable rail is fastened at the centre *o*, and also at the ends, by spike-nails *h*.

To facilitate the sliding, ground-plates must be laid down under the rails, or in default of these, ordinary fish-plates *l*.

If tongues are available, but the necessary wing-rails belonging to them are wanting, the latter may be formed without much trouble by bending ordinary rails according to a pattern made of laths.

When no constituent part of ordinary switches is procurable, a special arrangement has to be followed.

Instead of the ground-plates *p* (*Plate VII., fig.* 1), ordinary fish-plates may be used. The fastening at the pivoting points A and A^1 is effected at the root, as in the case of tongues of the usual form.

When there is no arrangement for altering the position of the points, the switch rods must be bent, and fixed as required.

§ 25.

Water Supply.

When a station is undergoing restoration, the re-establishment of the arrangements for the supply of water must be commenced simultaneously with the laying of the rails. The locality, and nature of the destruction effected offer the best data for deciding whether the restoration of existing, or the construction of temporary arrangements, is the more advantageous.

(*a*) *Tanks.*—If these cannot be brought into communication with the new sources of water, they may generally be disregarded. But if the ground on which they stand happens to be favourable for conducting the water, they should certainly be turned to account.

Unimportant damage done to iron tanks may be remedied; thus, small holes in the sides or bottoms may be closed by thin plates of

metal rivetted on, or merely by pieces of thin planking: splits and cracks must always be cemented or stopped up.

Where the damage is extensive, repairs of this description are very untrustworthy, and it will therefore be better to make use of a temporary construction, which may either be erected upon the tank, or may supply its place altogether. The simplest form of such construction consists of water butts or vats *a* (*Plate XII., fig.* 7), as nearly as possible of equal height, connected by pipes from 4 to 6 inches at least in diameter, and having a conduit pipe or hose *c* attached, of the same size.

If the buildings connected with the water supply are found demolished, or if it should be necessary to form at any place an elevated position for a tank, a strong combination of trestles will probably answer the purpose (*Plate XII., fig.* 8); but as their erection takes time, it will be found, in most cases, that the simplest method of supporting the planking is by means of stacks of wood. For this purpose, the transverse sleepers which may be in store, or easily obtained at any station, will be found useful (*Plate XII., fig.* 7).

This description of temporary tank, with water tubs, may be erected at any desired point, and even near or between the lines of rail; and in these latter cases, cocks are superfluous, for the filling of the tender may be effected directly from the tubs.

(*b*) *Supplying the tanks.*—In a restored or newly-erected tank, the means of supplying it with water must not be forgotten. Destroyed pipes, leading from sources of water at a higher situation than the tanks, may be replaced either by open ditches or wooden gutters (*Plate XII., fig.* 9).

From sources of water at a lower elevation, the water must be raised by means of either pumps or Archimedean screws.

Permanent pumps, usually worked by steam, would probably be rendered unserviceable by an adversary; the condition to which they have been reduced by the demolition will determine whether their restoration or the substitution of an extemporised arrangement in their place is the more advantageous. It is impossible here to lay down any rules; the decision will be always governed by the consideration of the means at disposal, and other circumstances. But it does not appear superfluous to mention, that when only the main rod, the cylinder, or the valve has been taken away, and the well and rising-pipe are left uninjured, it is for the most part more preferable to effect a restoration than to construct an improvised machine. If, however, the well or rising-pipe has been destroyed, and there is not another in store, the simplest means to adopt is to requisition a complete pump from the nearest village to supply the place of the other. But if the well has

been rendered unserviceable, and there is no standing or running water in the neighbourhood, there is nothing else to be done but to clear it out and restore it to its original condition; or, at any rate, to make use of portable Schullhof wells, having first ascertained that the local nature of the soil offers no insuperable obstacle to the driving of the suction-tube of the pump, and that the depth to the water does not exceed the height of this tube (28 feet to 32 feet).

(*c*) *Feeding the Tender.*—For this purpose, water-cranes, usually placed at all watering stations, are very convenient, though not absolutely necessary; if they are found in an unserviceable state their restoration is unimportant, and still more so if the pipe connecting them with the reservoir is damaged. In this case the transition of the water from the reservoir wells or other source to the engines and tenders is most simply effected either by gutters, pipes, or india-rubber hose. The pipes, &c., should always be placed above ground, because they can then be more quickly laid down. The supports which may be necessary should be always 7 feet high at least.

§ 26.

Buildings, &c.

As the majority of the buildings which are found upon railway stations are only for greater convenience in administration, working, and the economical maintenance of *matériel*, they are not absolutely necessary for purposes of traffic. In cases of emergency, and especially in time of war, every thought of convenience and money is laid aside where time and labour can be saved. Hence it follows that everything superfluous may with care be avoided, and only what is necessary brought into a state of efficiency with all possible labour and means. Therefore, when stations are destroyed, no buildings except carriage sheds* should, as a rule, be restored. Care should be taken to construct ramps, and to place in order the necessary wells and drains.

There will be little difficulty in extemporising arrangements to take the place of the ordinary ramps. The masonry revetement may be replaced by planking *a* (*Plate XII.*, *fig.* 10), after which the ramp is formed with earth, or a staging of the simplest kind may be formed with planks.

The height of this ramp must be exactly that of the original; its breadth, however, may be reduced to a minimum; and in an extreme

* In the campaign of 1870-71 a goods shed, capable of containing 1,000 trucks, was erected at the Gonesse station. Large sheds were also built at the station at Mitry. The shape of such temporary sheds resembles that of large huts.

case, in place of the plateau, a very broad ascent (*b*), at least four times the base, may be formed. This last measure is, of course, only admissible when there is sufficient space, otherwise a plateau of the ordinary breadth must be made. Ramps of quite a temporary nature are shown in *Plate XII.*, *figs.* 11, 12; they are principally adapted for getting horses into the trucks.

§ 27.

Rolling Stock.

Locomotives and trucks which have been rendered unserviceable can only be repaired in permanent workshops; individual parts which are wanting may be replaced on the spot by special workmen. Extemporised arrangements are impossible.

§ 28.

Signals.

Directly the restoration of a railway is commenced, the visual signals must be erected, and the electric telegraph placed in operation along the whole line. Electric bell signals and ringing apparatus can be added afterwards.

PART III.

LAYING OUT NEW RAILWAYS.

§ 29.

Introductory Remarks.

In addition to the necessity of depriving an enemy of the use of railways, and of restoring lines which have been demolished, there may also arise the case of entirely new railways having to be laid down for military purposes. The necessity of constructing such railways may, for example, arise under the following circumstances.

(*a*) In order to connect existing railways, or contiguous stations.

(*b*) In order to connect fortified places or detached works, either with each other, or with existing railways.

(*c*) In order to bring rolling-stock from exposed stations into the interior of a fortress, or be able to transport it to a place outside the station to which no railway leads.

(*d*) In order to convert single lines into double ones, or merely to provide sidings.*

(*e*) In order to make stations more convenient for the requirements of a large traffic in troops, by increasing the number of lines.†

(*f*) In order to avoid portions of railway, which, from their situation are more especially exposed to destruction by an enemy, and to construct in their place a more sheltered line of communication.‡

(*g*) In order to avoid tunnels which have been destroyed, and which cannot be temporarily repaired. (*See* Nanteuil Tunnel, *Part II.*, § 16.)

* A case in point is the construction of a second line of rail between Winden and Wendenheim, and also between Weissenburg and Hagenau, by the Bavarian Field Railway Division, in the campaign of 1870-71.

† Rails were laid at the station of Gonesse, on the Oise, by the engineer Glaser, in the campaign of 1870-71.

‡ A line of this description was established between Romilly and Pont-à-Mousson by the German Field Railway Divisions 1 and 4, 1870.

(*h*) In order to establish direct lines of rail to points of strategical importance.*

The construction of railways of this description must naturally be completed in the shortest possible time. Hence it follows that it is not possible to observe all the rules of ordinary railway construction, but everything that is not absolutely indispensable must be omitted, and, as in the case of the restoration of a destroyed line, constructions of an extemporised nature must, as a rule, be only so far made use of when the safe working of the line is ensured for as long as may be required. Sufficient details for the execution of such constructions are given in Part II. Only the laying out of permanent lines will, therefore, be treated of here; it will, however, be shown (§ 36) how the works necessary for permanent lines may be simplified in the laying out of Field Railways.

By the laying out of a railway is understood, in the widest sense, all those preliminary operations which, executed in a definite order, facilitate the preparations for constructions, and after which the work may be undertaken on the ground.

These preliminaries consist of:—

I. General directions.
II. Rough survey and plan.
III. Detailed survey and plan.
IV. Taking cross sections.
V. Detail of levelling.
VI. Details of the whole project.

§ 30.

General Directions (*Programm*).

The general directions consist of a summary of all those points which serve as a guide to the engineer commanding in the execution of his designs. They embrace usually the following points:—

(*a*) *General statements as to the line.*—Whether there is to be a double or a single line of rail; whether the formation and main works are to be prepared for a double line, the permanent way material of one line of way being reserved until it is wanted; and whether the main works are to be so constructed in the first instance that, in case a second line is required, the existing constructions (bridges, viaducts, and buildings) may be equally made use of.

(*b*) *Gauge.*—Whether any other than the ordinary is to be adopted; and if so, what it is.

(*c*) *Dimensions of the rolling stock.*—Whether the ordinary headway

* Construction of the Bruchthal-Germersheim Railway by the Bavarian Field Railway Division in 1870.

and width in the clear are to be allowed to bridges, or whether special dimensions are to be adopted.

(*d*) *Breadth of embankments at the top*—what dimensions they are to have.

(*e*) *Maximum length of trains*—which will run on the line; this decides the length of stations and sidings, as well as the position of water-cranes, stores, &c.; it influences, too, the gradients and radii of the curves.

(*f*) *Maximum slopes.*—Accurate data on this point for the different conditions of ground.

(*g*) *Minimum radius of curvature.*

(*h*) *Nature of road-crossings*—whether level, or by means of bridges; the former, especially in towns, should be avoided as far as is practicable.

(*i*) *Situation*—distance and list of stations.

(*k*) *Nature of constructions in general*—and directions for the building of constructive works, whether they are to be of masonry, wood, or stone.

§ 31.

Rough Survey and Plan.

After it has been resolved to connect two places or points by a railway, those preliminaries must, in all cases, be gone through, which will decide which is the best line to be chosen, as well with regard to expense as traffic.

These preliminaries become especially important, when the two points to be connected are separated by water-sheds.

The first data for these preliminaries are to be found in any good map, for a single glance at it is sufficient to show approximately the extent and nature of the work to be undertaken. The most important elevations, their distances apart, the existing communications, the river-basins and valleys, will usually indicate the general direction which the line will have to follow.

This preliminary plan, when fixed upon, will be shown on the map in question. Together with this, the peculiarities of the neighbourhood must be carefully examined, and at the same time individual heights should be obtained barometrically. This examination gives a series of points with their relative attitudes, and shows those places where a double line of way is practicable, where stations may be placed, and of what size they should be, where depôts may be formed, and their approximate extent.

Guided by these results, and by the general directions, designs for

possible lines may be fixed upon, and from among these the most suitable is chosen.

§ 32.

Detailed Survey and Plan.

As soon as the rough survey has been prepared, it is divided into sections (Betriebstrecken), the length of which depends partly on the rise and fall of the ground, and partly on circumstances connected with the works considered expedient. On these sections, the detailed survey is commenced. This embraces all those proceedings which are necessary before the central line of the railway can be laid down. They are:

(*a*) *The reconnaissance of the country.*—By this is understood the survey and inspection of the country in all directions, in order that a general clear idea of the local peculiarities may be obtained. As exact a description as possible of the local geological condition of the ground should be given, as this has a considerable influence, as well on the nature of the work as on the obtaining of building material. As in such a general inspection, borings and sinkings are out of place, as taking up too much time, and as leading, in only very few cases, to correct results, and being of little use in a general survey, the characteristic indications at hand must form, as far as possible, a sufficient guide. From the nature of the vegetation it may be gathered whether the soil is mainly moist or dry, whether vegetable soil, clay, sand, or rock is present, and from this, whether land-slips or other dangers are probable; existing quarries, deep wells, and precipices, which show the nature of the beds of stone, are good guides. Similarly, the shape, nature, and size of river-beds should be observed, because from this the rapidity of the stream, in the event of the water rising, may be determined.

Not less important are the statements of the inhabitants in the neighbourhood of the different sections; they at least suggest in what direction investigations should be made as to the water-level floods, the temporary changes in the course of streams in heavy rain; the more or less frequent occurrence of such rain; whether streams ever become dried up, and want of water is to be feared, what places are exposed to accumulations of snow, or sand, &c.

In this examination also the price of labour and material should be inquired into, as well as the possibility of bringing up a large number of workmen. Technically speaking, such a reconnaissance serves also as a rough design; that is to say, the direction of the line in the section under consideration may be approximately laid down from observation.

(*b*) *Preliminary levelling (flying levels).*—As soon as the *reconnaissance* is completed, the actual technical work of levelling may be begun. The object of this preliminary levelling is to obtain the difference of level between the two ends of the line, as well as the heights of a series of intermediate points lying in and near the general direction of the line as decided by the *reconnaissance*. It should give a representation of the ground according to the heights of various points; on this account it is advantageous, before the commencement of the actual levelling, to fix on as many points as possible, such as blocks of stone, corner-stones of buildings, tops of rocks, &c.; on these the heights obtained by the levelling staff may be permanently shown. The actual levelling will be commenced from a point which either falls within the final plan, or is at least very near it. The heights are not to be taken too great, or accurate results will not be obtained; no point, therefore, will be levelled to which is so far distant from the position of the instrument that $\frac{1}{1000}$ Klafter* can no longer be read on the levelling staff with any degree of certainty.

As the process of levelling is here supposed to be understood, it need only be mentioned that in this levelling must be noted the height of the water at the time, the zero points of any water-gauges that may be found, the marks of the highest water level and inundations discovered during the *reconnaissance*, as well as all those points which generally may serve to modify the heights along the line of railway. (*Plate XIII., fig.* 1.)

The results obtained from the levelling must be graphically shown on a section.† On this, the longitudinal section of the contemplated line, observing the conditions laid down in the general directions, and the adjustment of the *remblai* and *déblai*, will be approximately shown. It is, therefore, important to observe at what points the laying out of the line requires special attention, and also whether the direction given can be adhered to or not. In the first case, all preliminary work connected with the levelling for the laying out of the line is completed as soon as the direction of the latter seems in consequence of the ground or other causes to be unalterable. But if another direction for the line appears possible, the development of the design (as indicated under *d* in this section) will probably show which is the most favourable trace. In the second case, however, the development of the line, which must always precede the geo-

* A Klafter is 6·2226 English feet, and is represented by the sign °.

† Brouillon tables are of great practical use in representing these sections; on these, spaces of 50° in length and 1° in height are marked by vertical and horizontal lines. The vertical scale (1″ to 8°) is taken at ten times the horizontal.

metrical work, must be undertaken in order to ascertain and to mark out the central line of the railway.

(*c*) *The triangulation.*—The extent of this plan must be as limited as possible; it will only be increased at places where the line has to be carried through hilly and mountainous country. This must show the principal elevations in the ground, the highest as well as the lowest, and also all those points where there are any striking changes between the relative heights or slopes; the object of this survey is to obtain an accurate plan of the levels of the country. The fixed points determined in the preliminary levelling may here be made use of with advantage. The method of procedure, both for triangulating and for representing the levels, is supposed to be understood. The work is considerably shortened if correct maps are to be had, the levels and fixed points being merely inserted upon them.

(*d*) *Fixing the line by means of trial sections.*—By this expression is understood the determination of the line of intersection of the plane of levels (fixed by the preliminary levelling) with the ground. This is shown on the ground by pickets, and laid down on a plan. The way in which this is done, with the help of a level and of a longitudinal section obtained from the preliminary levelling, will be afterwards shown by means of an example. As a starting-point for the work only such points on the line should be chosen from which it is not possible that the final line will greatly deviate, and which are therefore fixed by local circumstances; or in which slight displacements can produce no important alterations in the line. Such points are: the bridges of a water-shed, or those situations in the direction of the railway which are closely bounded by hills, rocks, ponds, marshes, canals, or other artificial constructions. How far apart and how numerous the trial sections should be, depends on the nature of the ground.

The following example shows the method of taking trial sections: *Plate XIII., fig.* 2, is a contoured plan, the vertical interval between the contours being one Klafter (6 feet)—the longest contour is 51 Klafter, and the highest 56 Klafter—above a given datum. A, $\frac{VN}{1}$, $\frac{VN}{2}$, $\frac{VN}{3}$, ... are points obtained in the preliminary levelling (*Plate XIII., fig.* 2*a*, is a longitudinal section of this levelling), the line of levels falling 1 in 110, by which, at the point A, $\left(\frac{VN}{0}\right)$ the level is found to be 6 feet below the level of the ground. Now in order to obtain a more favourable slope for the final line, a lesser slope is tried, 1 in 130 for example. Let the point A be the starting-point, the ground-height and levelled height of which are known from the preliminary levelling. Under the corresponding

heads in the development table are first noted the ground-height and levelled height of the point A, together with the difference between the two; thus, under the head 'Level rises'—'falls'—will be entered the slope (here in the case taken there is a fall of 1 in 130). At the point A, a picket with a sharp point is driven into the ground, and marked $\frac{EL}{0}$, and entered in the table as 0*; the level is then placed with its axis exactly over the point A $\left(\frac{EL}{0}\right)$, and made horizontal; the height of the instrument (say 0·697°) is measured, and entered under the head 'Back reading' in the table. The height of the line of sight of the instrument above the datum is now calculated by adding the height of the instrument to the height of the point A (0·697° + 56° = 56·697°); the result is entered under the head 'Height of line of sight.' If now the levelled height be subtracted from the height of the line of sight, the height of the line of sight above the plane of levels is obtained (56·697° − 55° = 1·697°). The person with the levelling-staff places himself as nearly as possible in the direction of the trace, at a distance depending on the formation of the ground, and gives the distance in paces to the engineer. The latter then calculates the height of the line of sight above the line of levels. Suppose this distance is 75 paces =30°; then the difference of height for the slope 1 in 130 is 0·2307°; this, added to the height of the plane of the line of sight above the line of levels at the point A, gives 0·2307° + 1·697° = 1·9277°, or 1·928°. At this height the levelling-staff must be set, and it must then be moved to the right or left (keeping as nearly as possible the same distance off—30°), until the line of sight is directly upon it. As soon as this occurs, a picket $\frac{EL}{1}$ is driven into the ground, the levelling-staff is again held up resting on the top of the picket, and the level directed upon it; the height thus read on the levelling-staff is entered under the head 'Forward reading' for the point $\frac{EL}{1}$ (*ex. gr.* 1·925°). This height, being subtracted from the height of the line of sight at A (56·697), gives the exact height of the top of the picket at the point $\frac{EL}{1}$, which is noted under the head 'Height of picket' (56·697° − 1·925° = 54·772°). Meanwhile the distance of the point $\frac{EL}{0}$ from the point $\frac{EL}{1}$ is accurately measured with the chain, and entered under the head 'Intermediate Distance' (*ex. gr.* 29·8°). If this

* To fix this point with greater security, a second picket is usually driven into the ground from 3″ to 4″ distant from it.

measured distance (29·8°) does not agree with the paced distance (30°), the point $\frac{EL}{1}$ does not lie exactly in the plane of the levels. If now it is calculated how great the difference of height between the points $\frac{EL}{0}$ and $\frac{EL}{1}$ along the levelled plane should be for the accurately measured distance (for 29·8° with a fall of 1 in 130, this is 0·229°), and this is subtracted from the levelled height at the point $\frac{EL}{0}$ (55 − 0·229° = 54·771°), the thus found height for $\frac{EL}{1}$ (54·771) being entered under the head 'Height of the line of levels,' the difference between this calculated line of levels and the height of the picket at the point $\frac{EL}{1}$ is shown (54·772° − 54·771° = 0·001°); the result is then entered under the head 'Difference,' having a + sign if the height of the picket is greater, and a − sign if it is less than the calculated height of the line of levels in this case; therefore the difference is + 0·001°. The instrument is now removed from the point $\frac{EL}{0}$ to $\frac{EL}{1}$, placed exactly over it and made horizontal; the next point $\left(\frac{EL}{2}\right)$ is then determined in the manner just explained,* and so on throughout the whole length of the line completed. It should here be remarked that the difference entered in the table between any two consecutive points may be checked by adding the positive difference to the height of the line of sight, and subtracting the negative from it; by this proceeding the transmission of any small and unavoidable error is prevented.

In addition to the accurate determination of the difference of levels of the various points, the angles which the lines joining the pickets make with one another must be measured; this is done simultaneously with the determination of the points. When the third point $\frac{EL}{2}$ is fixed, the angle at $\frac{EL}{1}$ is measured from this point, and the result entered in the table.†

* In the table it is assumed, for the discovery of the point $\frac{EL}{2}$, that the distance paced and afterwards measured with the chain from $\frac{EL}{1}$ to $\frac{EL}{2}$ amounts to 50°, and that the height of the picket agrees with that of the line of levels.

† Railway engineers are accustomed, in order to prevent errors, to measure all angles, without exception, from left to right; thus the telescope is first brought into

Under the head 'Remarks' in the table, such points are to be noted, as where a line passes near houses, or where, owing to the ground, it could not be laid out without great expense, &c.

When the whole line has been marked out on the ground by means of pickets, and plotted on paper, this broken line, at present useless for the axis of the railway, must be converted into one which is in keeping with the requirements necessary for curves, and which adapts itself as advantageously as possible to the local formation of the ground, with regard to the due equalisation of *remblai* and *déblai*.* (*Plate XIII.*, *fig.* 9.)

The line thus obtained (central line of the railway) will naturally be shorter than the originally plotted line, and will therefore have also a greater slope. But in order that the gradient may in no place exceed the levelled line obtained from the preliminary levelling, a smaller slope is chosen for the determination of the originally plotted line.

The final line consequently, which lies between this line and that obtained from the preliminary levelling, will everywhere remain within the gradient limit, and at the worst can only reach the maximum of the preliminary levelling. From experiment it has been found that the above condition will be complied with, if

the slope of	1 in 100	is decreased to	1 in 130
,,	1 in 150	,,	1 in 175
,,	1 in 200	,,	1 in 220
,,	1 in 300	,,	1 in 315
,,	1 in 500	,,	1 in 510.

the direction of the back station $\frac{EL}{0}$, and the reading on the vernier in this position of the instrument (*ex. gr.* 126° 47′) is entered in the table under the head 'Back angle;' the level is then turned round from left to right until the line of sight is directed upon the staff at the picket $\frac{EL}{2}$. The angle thus given (295° 1′) is entered in the column 'Forward angle;' then, to calculate the proper angle to place in the column 'Angle,' we have 295° 1′ − 126° 47′ = 168° 14′.

It often occurs that the vernier of the level passes over the division 360° : in this case, in order to obtain the right angle, 360° must be added to the forward angle, and the back angle subtracted from the sum (*ex. gr.*):—

Back angle = 247° 34′.
Forward angle = 73° 13′.
Angle = (73° 13′ + 360°) − 247° 34′ = 185° 39′.

* For laying out the curves, arcs of different radii are formed of strong cardboard, and on the same scale as the detailed survey. These are fitted on to the plotted line, and moved and adjusted until a continuous line formed of straight and curved portions is found, answering to the above conditions.

§ 33.

Marking out the Central Line of the Railway.

That direction for the railway which has been decided on as the most suitable after a series of trials is now laid out on the ground; the straight lines are transferred and produced until they cut each other, by which are obtained the cutting or angle points, which are marked by poles from 9 feet to 12 feet high. In order to distinguish these angle-point poles, they are provided at the top with two small boards, from 12″ to 15″ long, and 6″ broad, nailed together, and crossing each other at right angles; on these may be marked the number of the angle-point, the size of the angle, or other facts. If on very long straight lines intermediate points are necessary, these are also marked by poles, which, in order to distinguish them from the angle-point poles, have only one board attached. The angle-points (Nos. 1 and 2, *Plate XIII., fig.* 9) are of use, not only for marking out the central line of the railway, but are also of great importance during the whole work of construction; they are the only means by which accuracy is obtained, and they must, therefore, be well secured in the recognised manner.

When the angle-points are fixed, the angles are accurately measured, noted, and the arcs laid down.* The last operation consists in determining points on the curve,† and in laying out the intermediate arcs necessary for the construction.

(*a*) *Marking out the points on the curve.*—If AB and CB (*Plate XIII., fig.* 3) are the straight lines, cutting each other in the point B, n the measured angle, R=DO the known radius of the arc, the point D the commencement of the arc, F its end, and E its middle point, then

$$\text{the angle } m = 180° - n,$$

$$\text{BD} = \text{BF} = \text{R} \tan \frac{m}{2},$$

and,

$$\text{BE} = \text{R} \left\{ \sec \frac{m}{2} - 1 \right\}.$$

Now in order to lay out these three points D, F, and E upon the ground, the instrument is placed over the angle-point B, and by observing the lines BA, BC, and the line BO, which bisects the angle n, the distances BD, BF, and BE, determined by the above calculation,

* For this purpose Kröhnke's *Handbook for Laying Out Curves* is recommended by railway engineers as being very useful, as it gives constant factors (tangent lengths, arc-distances, &c.) arranged in a tabular form.

† In railway plans these guiding points are designated as BA (commencement), BM (middle), and BE (end).

are plotted; thus the points D, F, and E are obtained, and are marked by pickets. With very long curves it is advantageous to fix more points, *ex. gr.* J and K; these are found as follows:—

$$DG = HF = R \tan \frac{m}{4},$$

$$BG = BD - DG = R\left\{\tan \frac{m}{2} - \tan \frac{m}{4}\right\} = BH,$$

$$GJ = HK - R\left\{\sec \frac{m}{4} - 1\right\}.$$

When these lengths are calculated, the points G and H are immediately fixed by marking out the commencement and end of the curve (D and F) upon the ground. Both these points G and H are then regarded as angle-points, over which the instrument is placed set at the angle

$$DGO = FHO = \left\{90° - \frac{m°}{4}\right\}.$$

By observing along GO or HO, the calculated distance GJ and HK can be plotted.

If the angle-point is inaccessible, or is so situated that no angular or other measurements can be taken from it, the points on the curve must be fixed by the following method.

Two points, G and H (*Plate XIII., fig.* 4), are taken in the lines AB and BC respectively, the distance GH is measured, and also the angles a and b; then in the triangle GBH, the angle c may be calculated, as well as the two sides BG, BH, and the lengths GD and HF.

Thus,

$$\text{the angle } c = 180° - (a+b),$$

$$OD = OF = R,$$

$$BG = \frac{GH \sin a}{\sin c}.$$

$$BH = \frac{GH \sin b}{\sin c}.$$

Again the angle $m = 180° -$ the angle c,

$$BD = BF = R \tan \frac{m}{2},$$

the distance of D, the commencement of the curve from the auxiliary point G:

$$GD = BD - BG = R \tan \frac{m}{2} - \frac{GH \sin b}{\sin c},$$

and the distance of the end of the curve F from the auxiliary point H:

$$HF = BF - BH = R \tan \frac{m}{2} - \frac{GH \sin b}{\sin c}.$$

This distance, being set off from the auxiliary points G and H along the corresponding lines, gives the points of the commencement and end of the curve.

If the auxiliary line cannot be taken from the angle-point, two auxiliary points N and M are taken, in the prolongation of the lines AB and CB, the line MN is measured, as well as the angles p and q; the angle c, and the sides MB and BN, are then calculated in the triangle MBN. Thus

$$\text{the angle } c = 180° - (p + q),$$

$$\text{MB} = \frac{\text{MN} \sin q}{\sin c},$$

$$\text{BN} = \frac{\text{MN} \sin p}{\sin c};$$

the centre-point angle

$$m = 180° - c,$$

and the line

$$\text{BD} = \text{BF} = \text{R} \tan \frac{m}{2}.$$

Again,

$$\text{ND} = \text{NB} + \text{BD},$$

and

$$\text{MF} = \text{MB} + \text{BF}.$$

In the triangle MNF the sides MN and MF, and the included angle p, are known; in the triangle NMD, the sides MN and ND, with the included angle q, are known; therefore in the first triangle, the angle w, and in the second, the angle v can be calculated; thus

$$\tan w = \frac{\text{MF} \sin p}{\text{MN} - \text{MF} \cos p},$$

and

$$\tan v = \frac{\text{ND} \sin q}{\text{MN} - \text{ND} \cos q}.$$

If these two angles are calculated, they can be laid out with the instrument at the points M and N of the auxiliary line; the points D and F give the commencement and end of the curve.

(*b*) *Marking out the intermediate points on the curve.*—For this purpose the following methods are usually employed.

I. The method already described, viz. by a continued bisection of the angle at the centre-point, until the necessary number of intermediate points has been obtained.

II. By means of abscissæ and ordinates.

If AB and BC (*Plate XIII., fig.* 5) are the directions of the straight

portions of the line; A the commencement of the curve; AHC the curve which has to be laid out; AO = R, its radius; AD = a, an abscissa taken; and DE = x, the co-ordinate to be calculated: then

$$x = R \mp \sqrt{R^2 - a^2};$$

or,

$$x = \frac{a^2}{2R}, \text{ nearly.}$$

With this formula, the curve may be laid out from any tangent whatever.

III. By means of a theodolite. If A (*Plate XIII., fig.* 6) is the commencement of the curve to be laid out, AO=R the radius; AC the tangents (the directions of the straight portions of the line), AB, BD, DE, EF, &c., chords of known and equal length; then the angles CAB, BAD, DAE, EAF are equal, and each is equal to $\frac{AOB}{2}$;

or,

$$n = \frac{m}{2}.$$

Each chord

$$= 2R \sin \frac{m}{2} = 2R \sin n,$$

and

$$\sin n = \frac{AB}{2R}.$$

From this formula, AB and R being known, the angle n may be found by the help of a trigonometrical table, and the curve may then be easily laid out.

Now in order to lay out a curve according to this method on the ground, a theodolite is placed over the starting-point of the curve, and directed along the tangent AC; it is then turned round to the amount of the calculated angle n, the length of the chord (10° at most) taken is plotted along this line of sight, and thus the first point B of the curve is found. The instrument is then turned round to the angle $2n$, the length of the chord (10°) is measured on from the first point B of the curve, the instrument is accurately directed along AD, and thus the second point D of the curve is found. In this way, as many points of the curve as possible are observed from one station.

If the instrument has to be moved, it is placed over the last point determined in the curve F, directed on its former position A, and from this along the direction of the tangent FN; the latter is obtained by turning the instrument round through an angle the same number of times n as there have been points fixed on the curve from the first

position (*ex. gr.*, here through an angle $4n$); the other points are then found in the manner already described.

IV. The curve may be laid out by trial; from the point A (*Plate XIII., fig.* 7), any length Ab is taken, and from b a perpendicular of any length is let fall, and the point 1 is marked by a picket. To determine a second point on the curve, the line A1c is drawn, and 1c is made equal to Ab, and the perpendicular $c2$ equal to $b1$; then 2 is the point required. The line 12d is now drawn, 2d is made equal to 1c, and $d3$ equal to $c2$; thus a third point of the curve is obtained, and so on, till the point B is reached With a little practice, the proper length at which to set off the perpendicular may be obtained at the second trial. In very thickly-wooded districts, this method of laying out a curve is often the only one possible.

§ 34.

Subdividing for Cross Sections, and Levelling the Line.

By subdividing is understood the splitting up of the final trace for the line into equal sections, usually about 250 feet or 300 feet long, and which are called station-lengths, profile-lengths, or profiles.

The points of division are marked in the field by pickets, which are numbered consecutively with Roman figures, and have the corresponding picket-level marked. At the same time, all points on the line at which the ground changes its slope, or at which work has to be executed, must be marked with pickets. These points are marked with consecutive letters of the alphabet, and in such a way that after each profile-picket a fresh alphabet begins. Cross sections are now taken at all the points indicated by the subdividing. (*Plate XIII., figs.* 8 *and* 9.)

As soon as a sufficiently long portion of the line has been subdivided, and the pickets showing the changes of slope in the ground, &c. are marked, the detailed levelling in the exact direction of the centre of the line is taken. Properly speaking, this is only to limit the points fixed in the subdivisions. From the results of this levelling the longitudinal sections and the cross sections are drawn, and lastly the correct and final levelling for the line to be constructed is laid out on the plan.*

* The choice of the scale is entirely at the discretion of the engineer. The scale for the verticals is generally ten times that for the horizontals. The size of the scale should, as a rule, be such that heights up to about one-twentieth Klafter may be measured off.

The following scales have been found suitable:—

For longitudinal sections:—	Horizontal	1″ = 250 feet.
„ „	Verticals	1″ = 25 feet.
For cross sections		1′ = 12 feet.

After the completion of these preliminaries, the entire line is inspected, and all those points at which constructions—such as culverts, bridges, viaducts, arrangements for crossing of roads or rivers, retaining walls, &c. have to be executed, are shown with their principal dimensions on the longitudinal section; those points, too, must be ascertained at which it is proposed to erect signal boxes.

§ 35.

Working-drawings, &c.

The last operation before the commencement of the actual work of construction, and at the same time the most difficult, requiring, as it does, perfect knowledge in almost every particular of engineering work, is the execution of the working-drawings, &c. Generally a design to be worked out must embrace—

I. Complete longitudinal and transverse sections.

II. A map of the neighbourhood with the direction of the line shown upon it.

III. Fully worked out designs, with estimates of cost for the permanent way, formation, and all such works as bridges, viaducts, retaining-walls, tunnels, &c. and masonry work.*

IV. Calculations of the earth-and-rock-movement with cost.

V. Accurate specifications for the rolling stock, and arrangements for the working of the line, such as signals, telegraphic communication, the building of offices, waiting rooms, workshops, &c.

VI. A calculation of the amount of compensation for ground and houses, as well as the insurance against fire of all inflammable, covered-in buildings situated within a distance of 60 yards from the centre of the line.

VII. Estimate for various works, such as drainage, fences, planting, &c.

VIII. Estimate of interest on the capital, cost of management, and other outlays during the construction.

§ 36.

Special Proceedings in Laying out Field Railways.

Field railways, as a rule, are only of small extent. In laying them out, all difficult work is to be avoided as much as possible, such as the formation of deep or long cuttings, throwing up high embankments, blasting of rocks, large constructive works, &c.; marshes and ponds should be avoided.

* Masonry work is generally shown, like the cross sections, on the scale of 1 inch to 12 feet.

With regard to the gradients, one will generally be guided by the description of rolling stock to be used on the line, but it will generally be found that the gradients on existing lines may be exceeded; thus, on level ground, the gradient may be 1 in 120; in hilly country, 1 in 80; and in mountainous country, 1 in 40. It is the same in the case of the radii of curvature, which may be taken at 284·5^{m} on level ground, 189·6^{m} in hilly country, and 158·7^{m} in mountainous country.

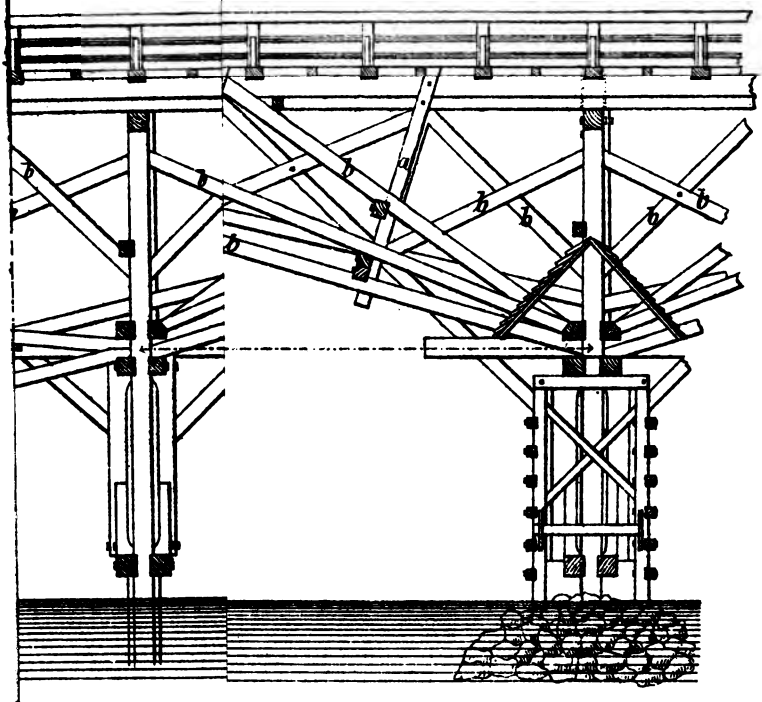
If the locomotives at disposal are of suitable construction, the radius of curvature may be diminished on all ground to 151·73^{m}, and likewise short lengths, i.e. up to 1000 yards, may have a gradient of 1 in 60, and longer ones a gradient of 1 in 70; it is, however, advisable, where possible, not to have the smallest radii of curvature and the steepest gradients occurring simultaneously at one and the same place.

In all cases, even in the most favourable, the following works must be completed before the commencement of the actual construction, viz.:

I. The reconnaissance of the line;

II. The setting out of the final centre line of the railway; and

III. Its subdivision and levelling.



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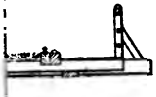


Fig 9.

ver the Luppe, Leipzig.

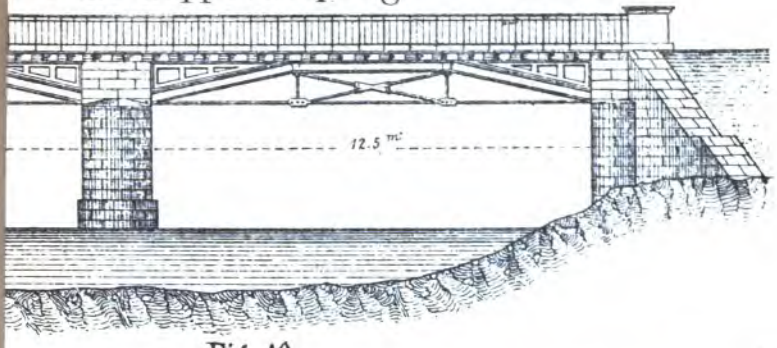


Fig 10.

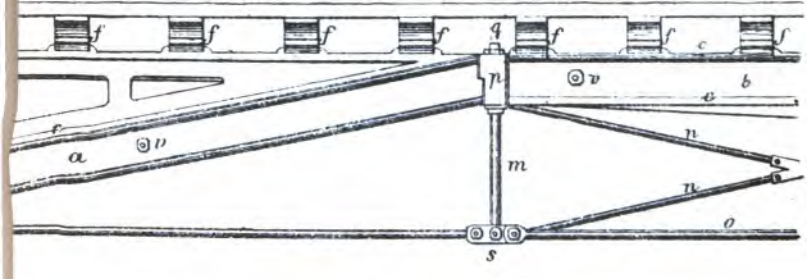
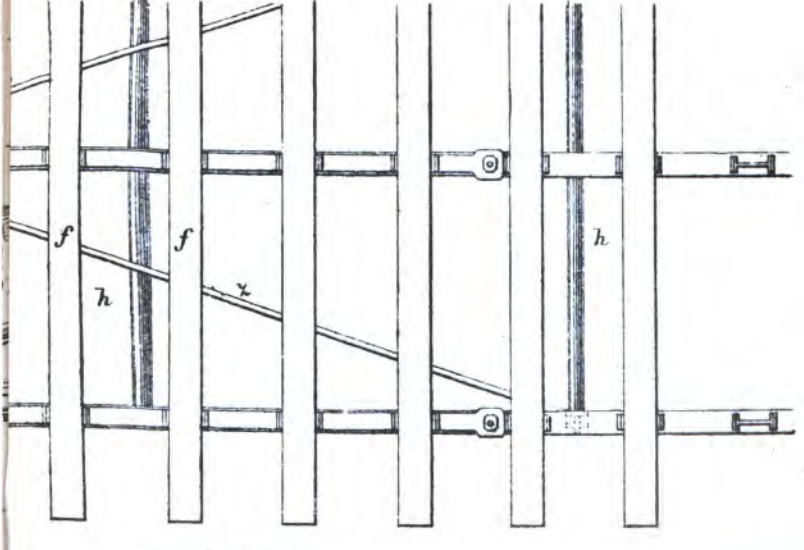
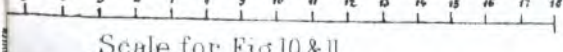


Fig. 11.



Scale for Fig 9.



Scale for Fig 10 & 11.

Fig 9.

ver the Luppe, Leipzig.

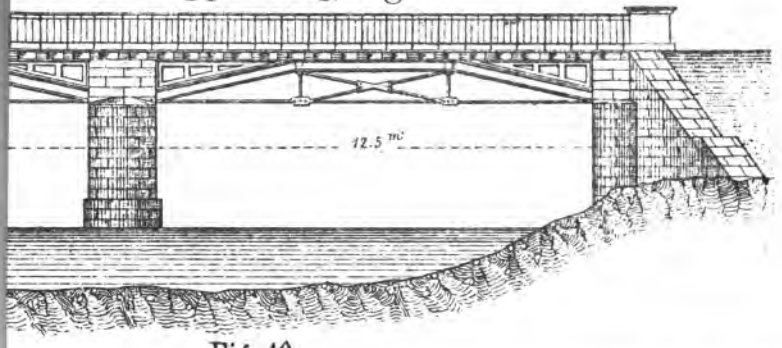


Fig 10.

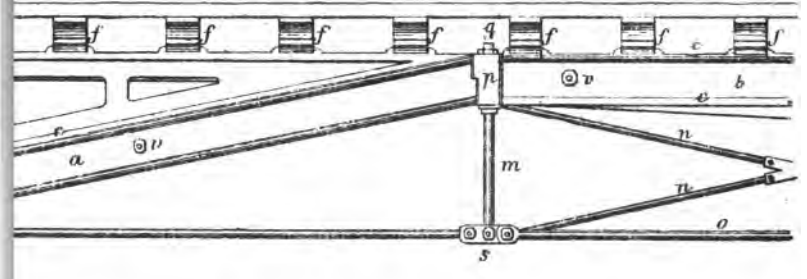
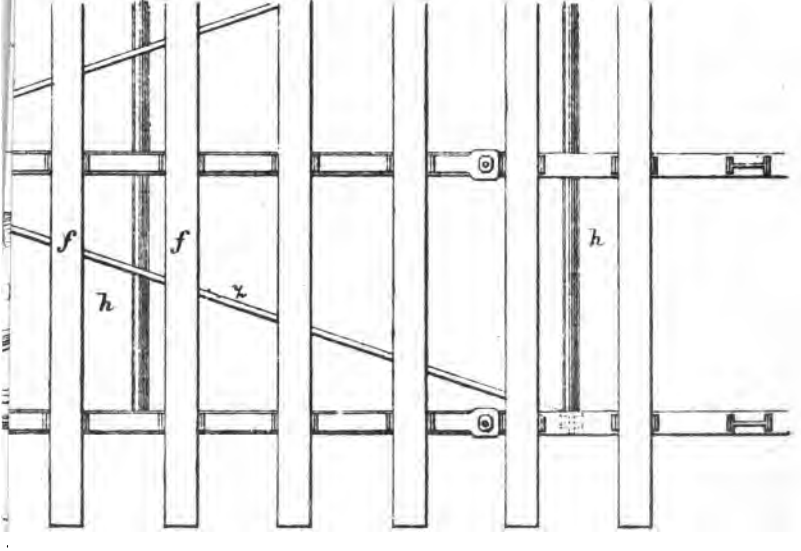
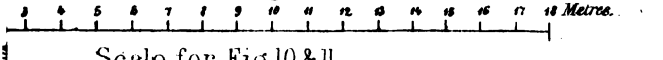


Fig. 11.



Scale for Fig 9.



Scale for Fig 10 & 11.

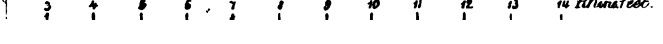
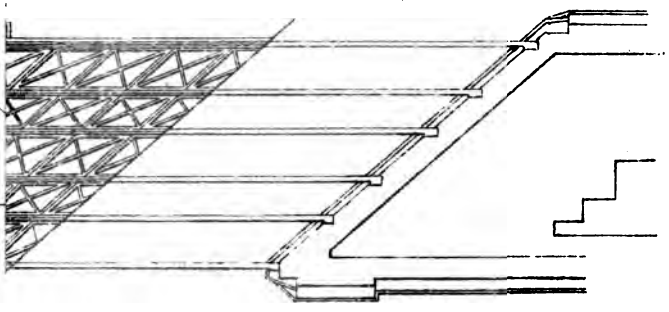


Plate III.

Fig. 4.



Scale for Figs. 3 & 4.

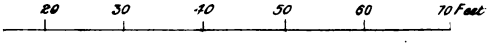


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Plate IV.

Fig.2.

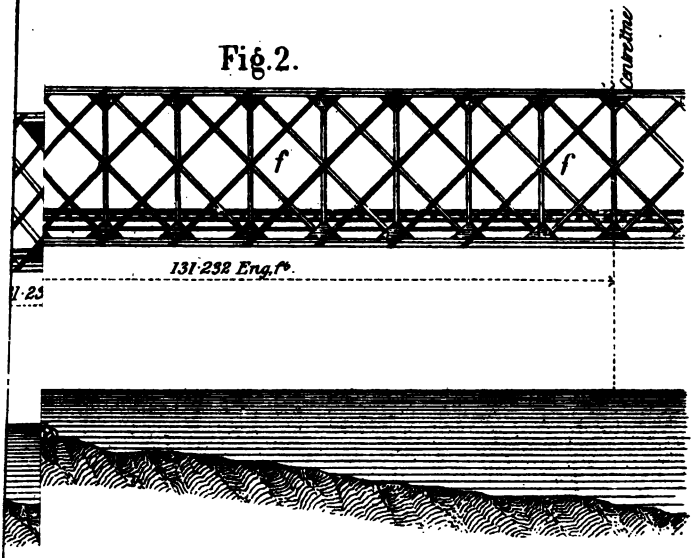


Fig.3.

Fig.4.

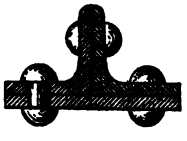


Fig.5.

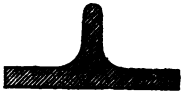
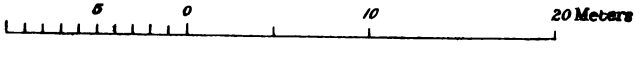


Fig.6.

Scale for Figs 1 & 2.



Scale for Figs 7 to 11.

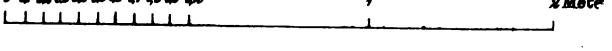


Plate V.

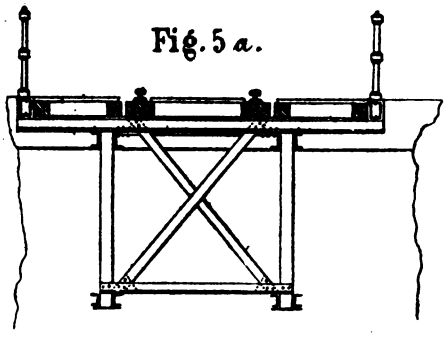


Fig. 5 *a*.

Scale for Figs 5 & 5a.

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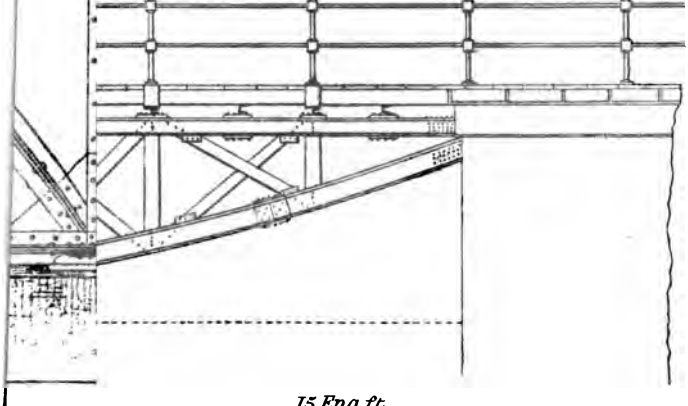
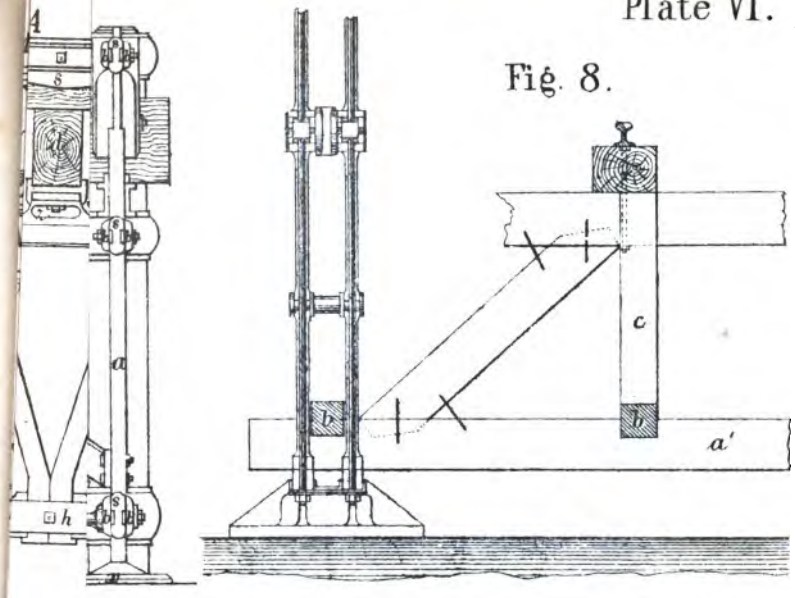


15 Eng. ft.

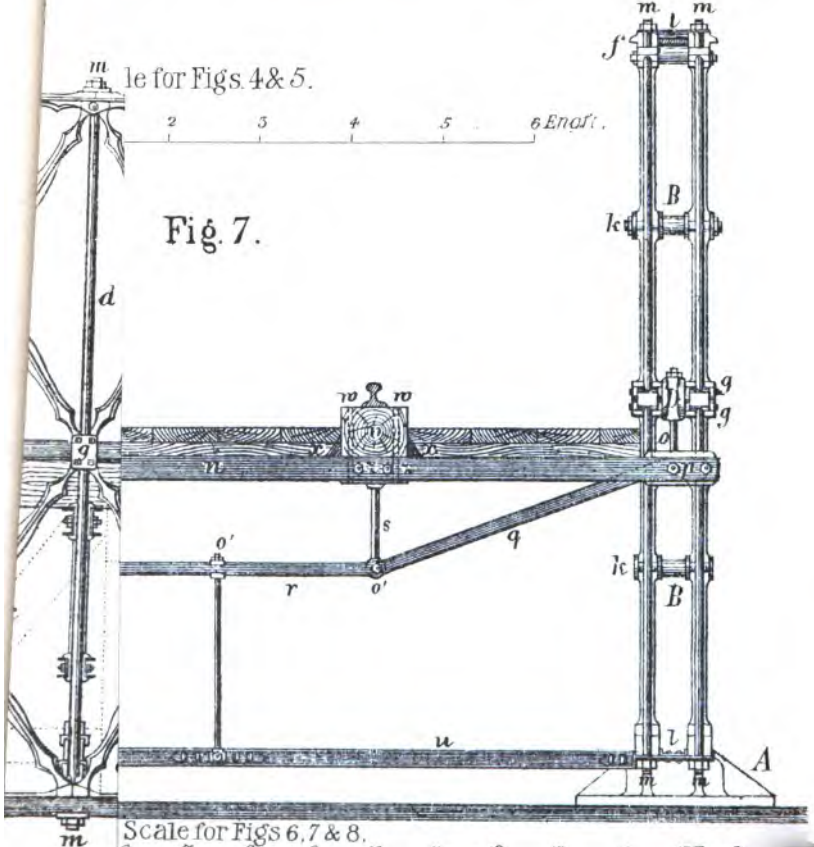
Fig. 8.



le for Figs. 4 & 5.

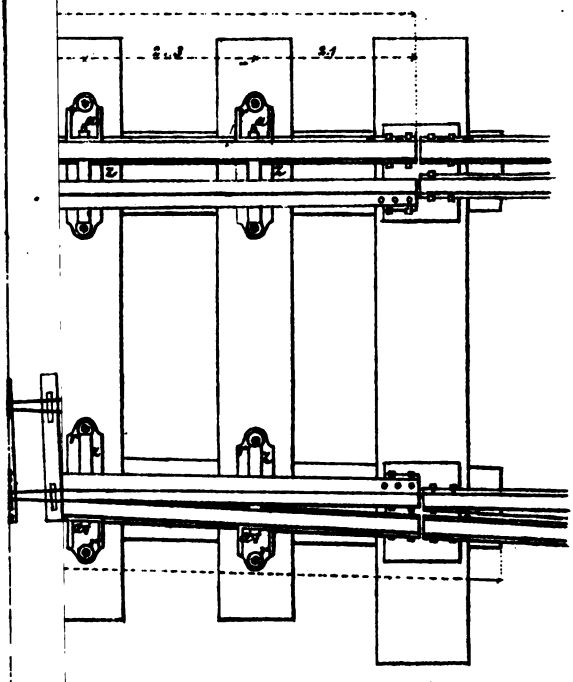
2 3 4 5 6 Engl't.

Fig. 7.



Scale for Figs 6, 7 & 8.

6 7 8 9 10 11 12 13 14 15 Engl't.



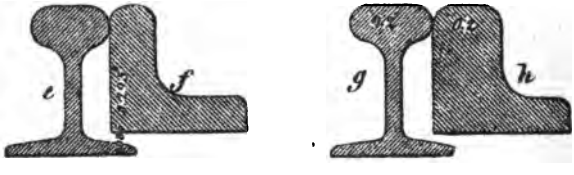
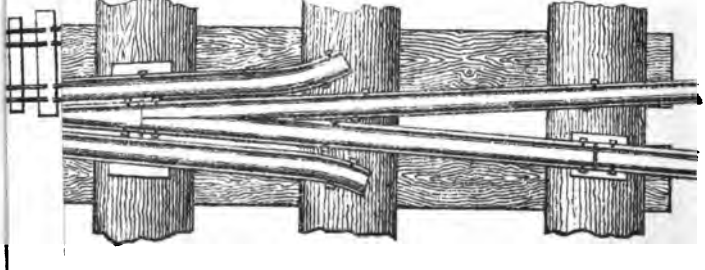
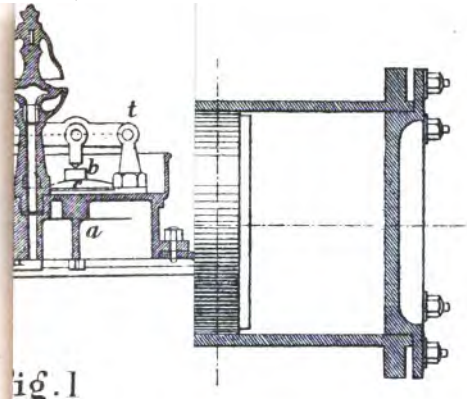


Fig 4.

Scale $\frac{3}{10}$.





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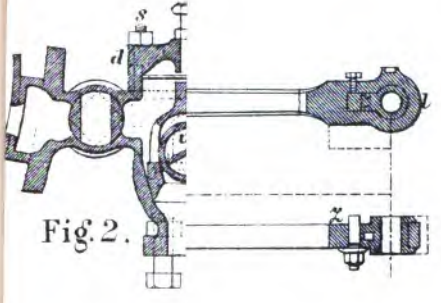

Fig. 2.

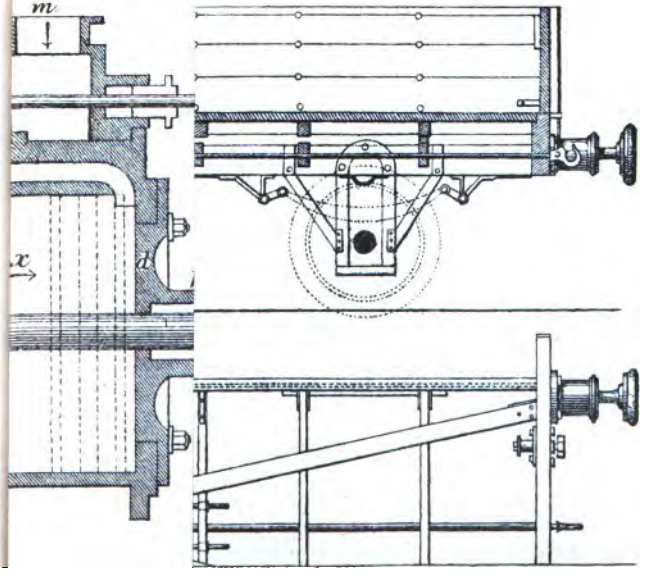

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Fig. 6.
Longitudinal Section.

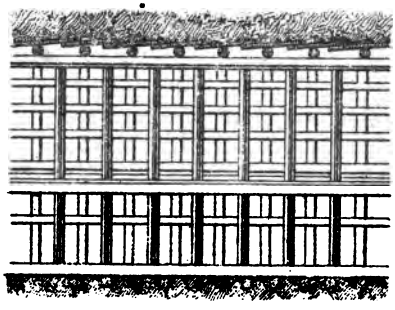
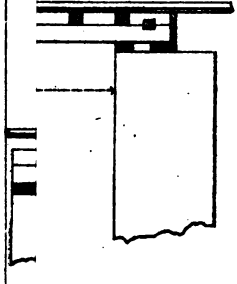


Fig. 14.
r Spans from 36 to 42 Eng. Feet.



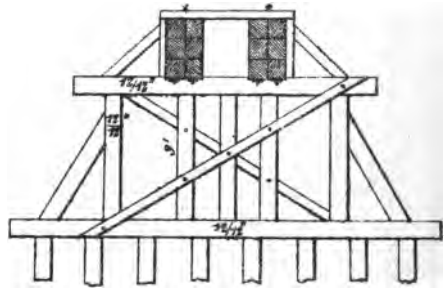
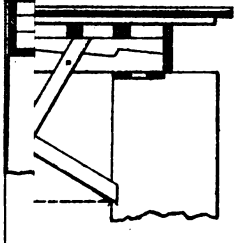


Fig. 15.



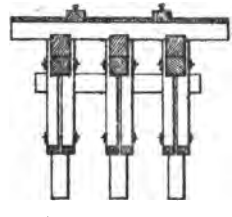
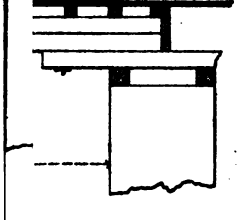
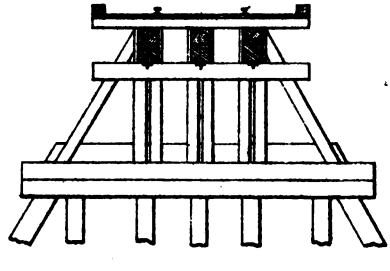
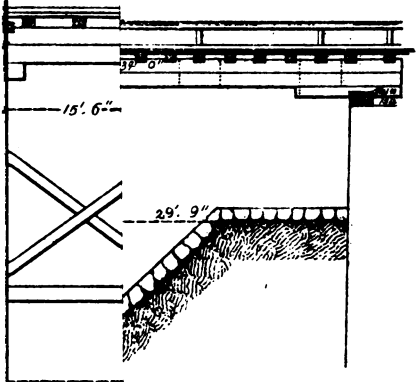


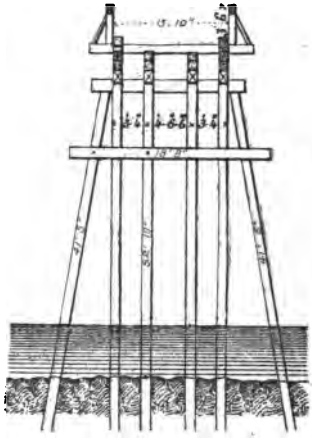
Fig. 16.

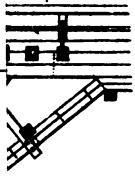


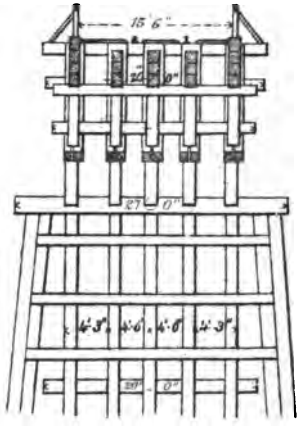


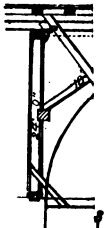
to 62 fe











Scale for Fig. 1 $\frac{1}{144}$.

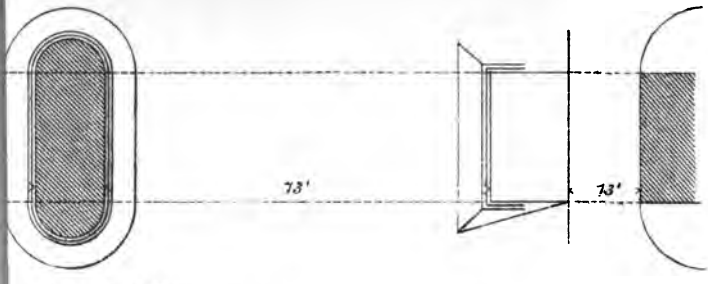
4° Austrian Klafter

Scale for Fig 4 $\frac{1}{288}$.

10° Austrian Klafter

Austrian Klafter = 6 fuss = 6·2223 Eng. ft.

Plate XI.



90 Rhine Feet

Cross Section.

2.

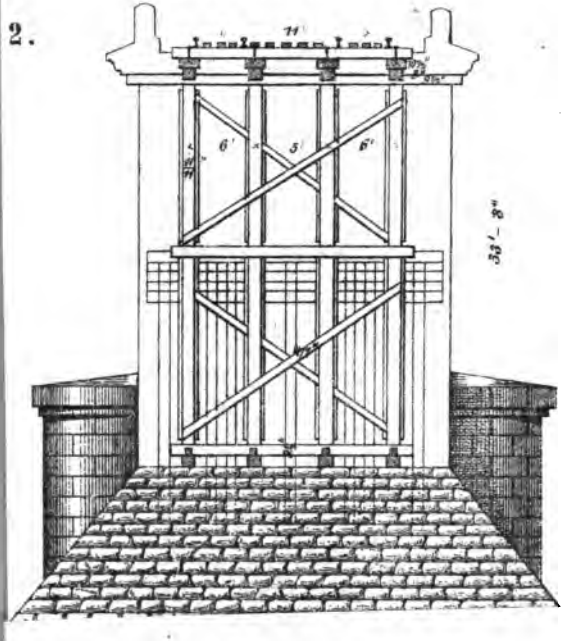
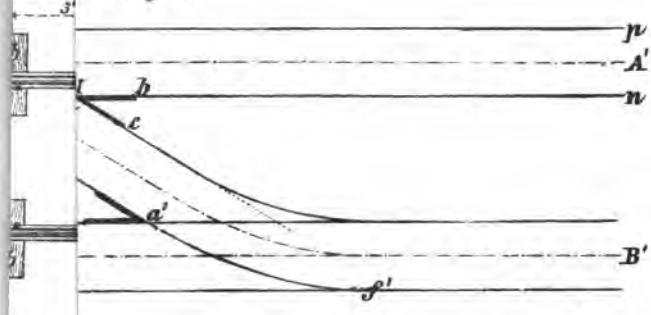


Fig. 1

Fig. 3.



Scale for Figs 1 & 2.

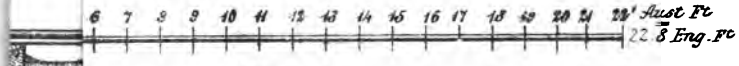
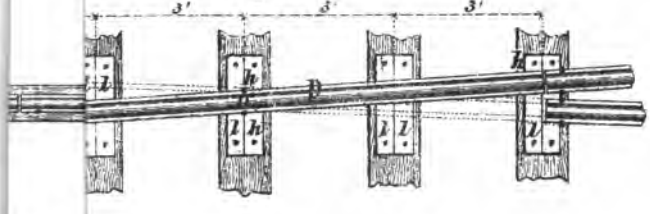
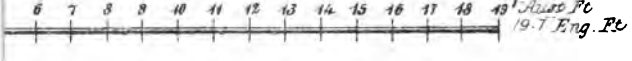


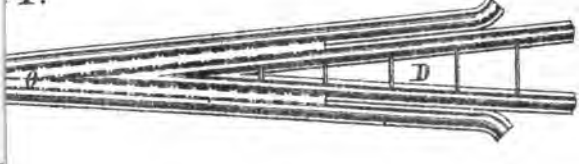
Fig 5.



Scale for Fig 10



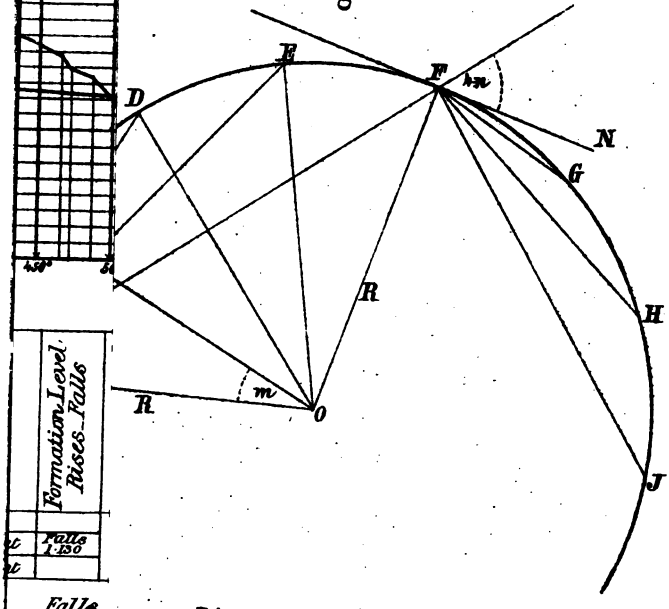
4.



Scale for Figs 5 & 6.

Scale for Figs 7 & 8.

Fig. 6.



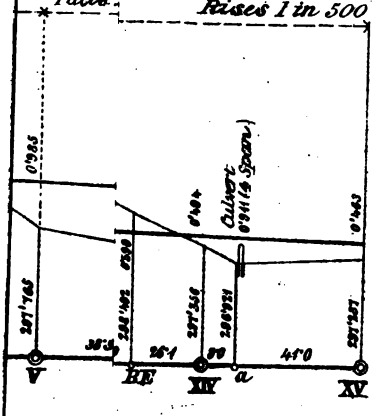


Fig. 4

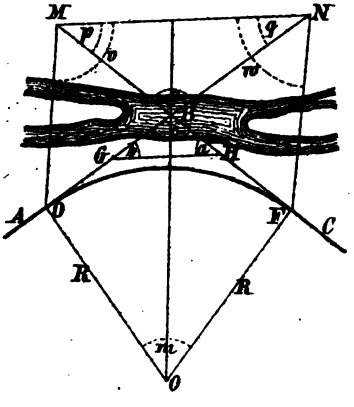
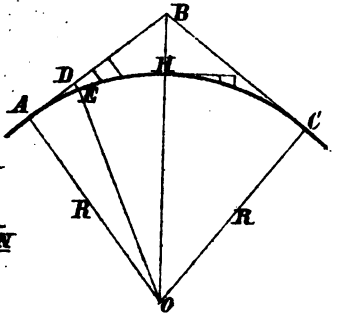
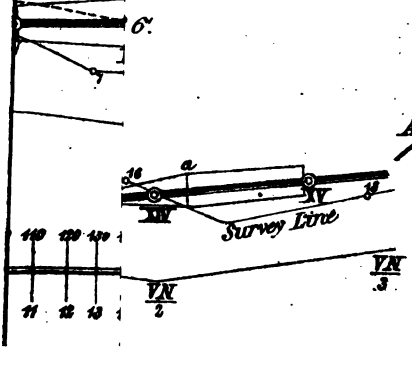


Fig. 5.





PAPER X.

THE MINE WARFARE.

AT SEBASTOPOL.

By Captain E. M. Lloyd, R.E.

The underground fighting at Sebastopol was not only one of the most interesting phases of the siege, and one to which the defenders look back with peculiar pride; it was also, perhaps, the most instructive example of mine warfare since the siege of Schweidnitz. But, as the English troops took no part in it, no account is given of it in the record of our engineer operations; and the Russian account was not published till 1870, when the attention of military men was directed elsewhere. As the works of General Todleben, and of General Niel are both of them bulky, and are not everywhere to be met with, an abridgement, giving an outline of the operations, will perhaps be useful to some officers of the Corps.

This may be confined to the mining in front of Bastion No. 4, known by the Allies as the Flagstaff Bastion, or Bastion du Mât, as the operations elsewhere were comparatively unimportant.

That Bastion was, in 1854, the French point of attack, and their approaches, pushed forward more rapidly here than elsewhere, were within 150 yards of the counterscarp by the 2nd of November. There they made their third parallel; but the close fire of the work now checked their further advance, and during the rest of the month they made no progress whatever.

They determined, therefore, if possible, to push forward underground, hoping "to make some heavy explosions near the Bastion du Mât, with the object of causing confusion there at the moment the assault should be given."

On the 20th November shafts were sunk behind the third parallel, and these having at length reached a layer of clay, from three to five feet thick, between two layers of rock, two galleries were

started on the 11th December. They were advanced at an average rate of six feet in twenty-four hours, their finished section being four feet high, and three feet six wide. No lining was required for them, as the sides stood well, and the overlying stratum of rock formed the roof.

The Russians foresaw this mode of attack, and on their side sunk trial shafts in November to ascertain how far the soil was suitable for mining. At a depth of about 16 feet below the surface they struck the same layer of clay as the French, and at once set to work, about the middle of December, to develop a system of countermines.

Three brigades were formed, to relieve one another every eight hours, each consisting of 75 miners and 200 infantry. Shafts were sunk in the bottom of the ditch of the Bastion, at distances of about 15 yards apart; an envelope gallery was formed to connect them, and listeners were pushed out from each of them to the front. The envelope gallery was made instead of a counterscarp gallery, which, owing to the irregularity of the line of the counterscarp, and the character of the soil, would have taken much longer to execute. The galleries were at first made three feet high, and two feet six inches wide, except when lining was necessary, as it was found to be in some parts; but they were afterwards enlarged near the shafts to assist the ventilation. This was a point that presented great difficulties as the listeners advanced, as the garrison had no good machines for the purpose. Transverse galleries were found to be the most effectual measure, and were largely used. Candles could not be burned at a distance of more than from 30 to 40 yards from the shafts, according to the weather and the number of workmen; all work beyond that distance had to be done in darkness, and daily suspended for some hours, so that not more than two or three feet of advance could be made each day.

Great pains was taken to teach the miners to catch the sound of other work going on, and to judge of its position. Four times a day work was stopped in all the galleries at once for about a quarter of an hour, that the enemy might be listened for; and it was then resumed successively in the several branches, so that the men might learn to distinguish the differences of sound according to the distance, and the tools used.

At about 30 yards the pick gave a dull indistinct sound at intervals; at something under 15 yards this became distinct and more continuous. Muffled work, or loading mines, could not be heard at more than $7\frac{1}{2}$ yards.

The extent of the countermines in the beginning of February is shown on *Plate* I.; the most advanced listeners—those near the salient—were about 50 yards long.

Meanwhile two shafts were being slowly sunk through the underlying rock, to ascertain if there were any lower stratum of clay of which the enemy might be taking advantage. Owing to the hardness of the rock two months' work only carried these down seven feet.

Information from a deserter gave the defenders reason to believe that the French were advancing upon the capital of the Bastion, on the same layer as the countermines; and this was confirmed by a plan of the siege, lithographed in Paris, which had been sent to them from St. Petersburg. Accordingly the listeners near the salient were pushed forward, and at the head of one of these, on the 30th January, the enemy's miner was at length heard at work. Next day he was near enough for the sounds of his tools and the creaking of his trucks to be distinguished. A chamber was therefore formed, and the mine was loaded and tamped. The line of least resistance was estimated at 18 feet, and the charge used was 435 lbs.; for Colonel Todleben had satisfied himself, by experiments he had made at St. Petersburg, that comparatively large charges might be used at slight depths, if the enemy were allowed to approach to within a distance less than the line of least resistance, so that the explosion might take its main effect along his gallery, and not upon the surface.

The rock layers were favourable to this lateral action; and to provide for it a length of 18 yards of the branch was solidly stamped with timber and sand bags.

The French were working unsuspiciously forward, hoping to take their enemy altogether by surprise. Their right gallery had advanced 120 yards, when, at 9 p.m. on the 3rd February, its progress was stopped, and the two leading miners were killed by the explosion of the Russian mine. The effect of this quite corresponded to the expectation of Colonel Todleben. A shallow crater was formed, which, when afterwards explored, was found to be about 4 yards long, $9\frac{1}{2}$ wide, and $2\frac{1}{2}$ feet deep; but the sound, as heard by the defenders, ran away towards the parallel, and flame and smoke were seen to issue thence. There was also a crack on the surface of the ground from the crater towards the parallel upon the line of the capital of the bastion. All this showed that, as was

actually the case, the French had been advancing on this line, and that the mine had taken effect along their gallery.

The Russians at once set to work to remove their tamping, in order to push forward to meet the besiegers; but after removing half of it, the rest was found to be so solidly wedged that it was easier to make a new branch alongside. They had not gone far however, when, on February 7th, the French fired a mine (F 1) too far off to injure the countermines, but showing that they were abandoning and blocking the more advanced part of their own gallery.

The French had, in fact, changed their plan of operations; and as soon as they found that there was no hope of surprising the besieged, it was decided to withdraw out of his immediate reach, and to push out branches right and left of the galleries to feel for him. By means of these a line of large craters was to be opened, in which a lodgment might be made half-way between the parallel and the counterscarp; and other mines were to be placed on the flanks to assist the making of communications from the parallel to the lodgment.

It was not thought worth while to dispute with the Russians, supported as they were by their artillery, the possession of isolated craters unable to hold strong guards, for the rocky soil made it difficult to establish good communications with them, and they lay nearer to the ditch than to the parallel. Accordingly the Russians occupied without hindrance the crater of the French mine; and sinking a 'Boule' shaft* 12 feet deep, they fired a charge of 325 lbs., which made a new crater 9 feet deep (R2). In this they sunk a new shaft to serve as a listener, and waited for the besieger. Meanwhile their miners, working with difficulty through the ground shattered by their first explosion—where large fragments of rock had to be broken up, and removed piece by piece,—had, by the 21st February, made their way into the gallery abandoned by the French, and held nearly 30 yards of it. They found it impossible, however, to work onward within the radius of rupture of the French mine, but branched out to right and to left.

On the 26th the besiegers had fired a camouflet insufficiently tamped, without much effect (F2); and on the 1st March they were heard at work, not only by the men established in the crater, but also in the listeners on the right and left faces of the bastion.

* A shaft lined with cases at intervals, for the rapid establishment of mines to be fired usually untamped.

It seemed that they were closing in on different sides at once. Three 'Boule' shaft mines were successively made and fired (R 3, 6, 8) from the crater lodgment, and three others (R 4, 5, 7) at the ends of three of the listeners. From these latter points the besiegers were actually at this time more than 70 yards distant, but the judgment of the miners was sometimes completely deceived by fissures in the rock. Other mines (R 9–12) were fired at the extremities of the branches run out from the captured gallery, as they were judged to be within good reach of the enemy. But before the last of these was ready the besiegers anticipated the besieged, and on April 7th fired a camouflet (F 3) which destroyed 13 yards of the branch, killed three men, and wounded two. This was the first loss the besieged had incurred in the mine warfare. "To efface the unfavourable impression which had been made on the soldiers by this explosion, Colonel Todleben caused an image of the Holy Saviour to be placed in the branch, and took energetic measures to deal the enemy on this same spot a blow equally severe." Five days later a mine (R 12) was fired here, having a charge of 780 lbs., and making a crater nearly 12 yards in diameter and 5 feet deep.

The Russians had expected that after the explosion of their first mine, which destroyed only about $4\frac{1}{2}$ yards of the French gallery, the French would at once push forward and fire an overcharged mine to destroy the countermines, and to form a crater in which they might establish themselves within 20 yards of the counterscarp. On their side they were prepared to dispute the possession of any such crater. But when they found that the besieger had abandoned 30 yards of his gallery, and week after week made no sign, they became apprehensive that he might have sunk to a lower stratum, and might be undermining their whole system of countermines, and even the bastion itself. They pressed on the two trial shafts already begun, and started six others, and after passing through 22 feet of rock they came in the early part of April upon another layer of clay, from 4 to 5 feet thick, and 42 feet below the surface of the ground. They at once began to form envelope galleries and to run out listeners in this layer, although by that time their fears as to the enemy's possible progress had been allayed, as they could hear nothing of him.

Above ground the besiegers' fire along the ditches of the bastion greatly embarrassed the mining parties, destroying the blindages which had been made over the mouths of the shafts, and making

the removal of the excavated earth a work of great danger and difficulty. At the same time the imminence of an assault made it unsafe to allow any accumulations in the ditch, which would interfere with its flank defence.

On the 8th April the second bombardment began, lasting ten days; and under cover of it the French endeavoured to push forward saps from the right and left of their parallel. Deserters at this time assured the garrison that the whole bastion was mined, and was to be blown up and stormed; and Colonel Todleben had great difficulty in subduing the panic excited by this news, and in satisfying the troops that the besiegers' overcharged mines, so long looked for, and now no doubt ready, must be quite out of reach of the bastion.

The French meanwhile had seen, by the increasing extent of the yellow clay deposits on the counterscarp, how considerable were the preparations made to meet them underground. They heard the Russians at work all along the front, and thought it best to remain on the defensive, with mines and camouflets loaded and tamped. They multiplied their branches, which by the 10th April numbered 36; and on the 11th they began to place charges for simultaneous explosion in 21 of these, viz.:—

6 of 4,180 lbs. each.
11 of 2,508 ,,
4 of 1,254 ,,

The four small charges were on the flanks to assist the formation of communications from the parallel, which it had been found very difficult to push forward under the fire of the bastion. To save time empty spaces were left behind the charges, and the branches were only partially tamped.

On the 15th April the mines were fired. Six of them failed to ignite, their fuzes being probably extinguished by the earliest explosions. The remaining fifteen (F 4–18) formed two very large craters* half-way between the parallel and the counterscarp, with pairs of smaller craters on either flank (see *Plate* II). The craters previously existing were almost entirely filled up. Little injury was done to the countermines, and only two men were killed in them; but in the bastion, and in the crater lodgment 30 men were killed, and 70 wounded by the stones thrown out. The French at once occupied the new craters with two companies, which were withdrawn at daybreak.

* Three, according to the Russians: they maintain that mines 6–13 did not form one continuous crater.

The Russians now assumed that the French, if they did not at once assault the bastion, would establish themselves firmly, and run out galleries from the craters for another row of mines. To hinder this, a continual fire from mortars was kept up on the craters, the countermines were pushed forward under them, and every effort was made to prevent the completion of the communications to them from the parallel. For some days the French made little progress. The rocky ground made it impossible to dig deep, so that the parapets had to be formed with gabions and sand-bags; and what was done in the night was usually destroyed next day by the fire of the Russians. But the besiegers' fire concentrated upon the bastion was so crushing, that by the 20th every gun was silenced, and on that night the sap was carried from the right of the parallel to the craters. These were soon afterwards connected and extended by firing five of the overcharged mines that had failed on the 15th (F 19–23), and two new ones (F 25 and 26). As it was found that the guard of the trenches, if they were placed in the craters themselves, suffered greatly from the mortar fire, a lodgment was made for them, early in May, behind the rearward rim, where they were much less exposed either to shells or mines, and where the craters formed a deep ditch along their front, giving them security against sorties.

Little progress, however, was made towards the bastion. In the mass of shattered rock forming the side of the craters the French found it impossible to strike afresh the layer of clay, and to push forward galleries. They confined themselves to holding their ground, and keeping the Russians in check, either by using the galleries already made, or by 'Boule' shafts, sunk and loaded hastily, wherever they were found to be advancing. "If we are in possession of one of the slopes the enemy remains pretty well master of the other," is the remark in the French journal at this time. For more than two months the combat continued in this way between miner and counterminer, without marked advantage on either side, and without much loss of life. The besieged fired thirty mines, averaging nearly 300 lbs. of powder; the besiegers thirty-three mines, averaging 600 lbs. The latter also fired several stone fougasses; and in tamping their shafts they took care to use sand-bags on their own side, and stones on the side of the bastion.

During this time the French extended their lodgment, making it their fourth parallel, and connecting it with the third parallel on the left as well as on the right. The Russians made additional

branches, and prolonged or repaired their old ones; and made transverse galleries for better ventilation. They also steadily continued their lower system of countermines. The French, for their part, had sunk trial shafts with a view to mining in a lower stratum, but abandoned them when they found how deep it would be necessary to go, because of the very large charges that this depth would demand.

On the 28th June two more overcharged mines (F 59, 60) were fired, one extending the existing craters to the right, and the other forming a new and more advanced crater upon the left (*Plate* III.) This evidence of an intention to work round on the flanks led the besieged at once to push forward and multiply their branches in these directions. But no advance was made from the new craters.

Everywhere the besiegers found themselves beset by the heads of the countermines, which in the centre even threatened the new parallel. To keep them in check five overcharged mines (F 75, 76, 78, 94 and 97) were fired in the old craters in the latter part of July and August. At the instance of officers, who had newly joined the mine attacks, it was determined, at the end of August, to run forward galleries from the craters of Nos. 94 and 97, which were favourable for this, as they were deep, and the clay bed was uncovered. But three days afterwards one of these galleries was completely destroyed by a countermine (R 77), and four men, who were in it, were only got out after an hour and a half's work. The other gallery was, therefore, discontinued.

Another mode of attack, however, was by this time giving promise of success. By means of successive 'Boule' shaft mines, two approaches, converging upon the capital, were gradually advancing, and threatened to cut in two the central galleries of the countermine system. The besieged found themselves unable to arrest these approaches, as the shaken soil, which would now hardly stand without support, delayed their work, and their wires frequently failed. By making additional passages they held on as long as possible to their network of advanced branches; but by the 4th September the two approaches were only separated by about 7 yards, and one well placed mine would have cut the last communication (*Plate* IV.)

By this time the most advanced branch of the lower system of countermines was within 20 yards of the 4th parallel (*Plate* V.), and it was determined to fire a heavy mine here. The line of least

resistance was reckoned at 31 feet to the bottom of the crater, which was itself 15 feet deep, and a charge of 4,325 lbs. was lodged. It was assumed that this would produce a one-and-a-half lined crater, into which most of the rock thrown out would find its way back again. The sudden disclosure of this lower system of countermines was expected to have a great moral effect on the besieger; and even if he should at once set to work to encounter them by sinking to the same stratum, a long delay might be confidently reckoned on. However, the capture of the Malakhow on the 8th September, and the consequent withdrawal of the Russians to the north side of the harbour, cut short at this stage the mining operations.

General Todleben, who is justly proud of his success in holding the besieger for so many months in check, at a point where his progress was at first so rapid and so threatening, draws particular attention to the small expenditure of men and material by which this was effected, and to the marked contrast in this respect between mines and artillery defence. The actual loss of the garrison by the mine warfare was 191, but of these only 24 were killed and 32 wounded in the mines themselves; the rest were struck in the bastion or its ditch. The French give their losses as only 4 killed in the mines, and 5 killed and 36 wounded by explosions in the craters. Many others were temporarily buried, or were suffocated while untamping. The powder used in the mines by the besieged was only one-half per cent. of that used by their artillery; and even in the case of the besiegers, it was only one-and-a-half per cent.

The Russian mines were fired by electricity. Out of ninety-four explosions only one failed by neglect, but in eight cases the wires had been broken by the besieger's explosions. The French used the Lariviére fuse * with the Bickford fuze. The usual rate of advance in the countermine branches was between 5 and 10 feet in 24 hours, according to the distance from the shaft. In the lower tier it never exceeded $2\frac{1}{2}$ feet. Where lining was found necessary cases were commonly used.

It was found sufficient to allow about 3 yards of tamping for every cwt. of charge, or about 1 inch per lb. Where an explosion was feared before a branch could be loaded, it was tamped without loading.

General Niel has found fault with the extreme irregularity of the countermine branches, which, from the time they encountered

* Quick match, protected by a waterproof envelope, and burning at the rate of 100 mètres a second.

the enemy, would seem to have been carried on almost without plan, as if each leading miner took his own line. Hence there was a much greater extent of branch than was required by the number of heads of attack; it must often have been impossible for the miners to distinguish between the sounds of their enemy's work and that of their neighbours; and any considerable explosion directed against the enemy was sure to injure some gallery of their own.

General Todleben replies to this criticism that such irregularity necessarily follows from the obligation to direct the branches from day to day according to the sounds of the enemy's workmen, and the mines he fires. This branch must be pushed forward; from that branch we must break out to the right; another, perhaps, has been destroyed, and a substitute must be made for it. Nor, as a matter of fact, were the inconveniences experienced, which, it is assumed, must result from this.

The lower system of countermines, in General Niel's opinion, involved more labour than the strength of the enceinte warranted. It was carrying too far the maxim, that "dans les mines celui qui a le dessous a le dessus." The mine of this system that was actually found loaded would have had little effect; for though it was unsuspected, yet, on account of the mines of the upper system, the French had no intention of massing troops in the craters. But General Todleben points out that this lower system would have allowed of the destruction of all the French galleries in the upper layer; it gave confidence to the miners in that layer; and if the besieged had neglected, and the besiegers had taken advantage of, this lower stratum, the whole of the countermine system and the bastion itself might have been destroyed.

The main conclusions to be drawn from the mine warfare at Sebastopol are thus summed up by General Todleben.

ATTACK.

"The besieger should advance by several galleries, taking care to secure those on the flanks by listeners. He must, however, be energetic and persistent in his attack, for the defence will turn every moment's delay to account in the development of his system of countermines, so as to arrange an attack by a superior number of listeners.

"Once within the sphere of the enemy's mines, the besieger, when he receives the first camouflets, must in no way slacken his advance even though some of his branches may have been struck.

"On the contrary, this is the very time that he must make every exertion to fire his overcharged mines in the galleries that are still uninjured, in order to destroy the countermines and so bar the way to the besieged.

"One can rarely attain one's end in such a case without suffering loss more or less heavy; but too much prudence and circumspection for the sake of avoiding loss will almost always result in complete failure for the besieger.

"Before firing the overcharged mines the besieger must have everything in readiness:—

"1. For occupying and intrenching himself in the craters immediately afterwards.

"2. For forming an open communication from the trenches to the craters by means of the sap, helped by intermediate explosions simultaneous with the overcharged mines.

"3. For constructing a certain number of shelters for the guards told off to protect the craters against sorties. For this purpose the French arrangement, before No. 4 bastion, of a parallel behind the rim of the crater may be recommended.

"After having occupied the craters, the besieger should push on from them at once with his galleries,—usually straight forward to continue the attack, but sometimes also laterally to secure the flanks and to connect the craters by mines between them.

"The galleries of attack must be long enough to allow of a tamping corresponding to the charges. If by any accident this cannot be complied with, heavier charges must be used to make up for the shortness of the galleries. The besieger should only use camouflets in exceptional cases, or when the counterminer is so close that he has no time for an overcharged mine. Even in this case the besieger should do his best to make his charge heavy.

"Supposing the besieged has anticipated the besieger, and has managed to surround the craters by a large number of branches, the besieger must then endeavour to sink below the countermines, or destroy them by 'Boule' shafts made in the surface strata. Moreover, if the fire of the place should be so violent as to make it alike impossible to establish a lodgment and to sink a shaft deep enough for a considerable charge, the besieger must begin with shallower shafts and small charges, so as first of all to break through the obstacles which the most advanced countermines present to him.

"After having fired these and occupied their craters, he must sink deeper shafts in those craters, and fire overcharged mines in them;

then he will at once occupy the new craters so made, and connect them with those already existing, and so continue resolutely to advance, employing such of the methods we have mentioned as may best suit his circumstances.

Defence.

"The besieged should push out his countermines as far as possible beyond the crest of the glacis, and secure them against attack from below, down to whatever depth the enemy can be supposed to be advancing at. To connect the galleries by transversals is the most effective means of ventilating them, and these transversals should form salient angles towards the country. A series of transversals so made will constitute an envelope gallery of indented trace. With the same object it will be useful to bore holes in the galleries up to the surface of the ground.

"Suspending work several times a day, the besieged should listen attentively to discover the work of the attack in good time. Having caught in one of the branches the sound of the enemy's miner, the counterminer should continue to advance towards it, working noiselessly, or else at once form a mine chamber and load it, and then wait, listening at the point where the fuse trough comes through the tamping, until the enemy is near enough. At all other points, where the enemy is not yet to be heard, the besieged should continue their work vigorously.

"The true judgment of distance by carefully listening to the enemy's workman is a point of the utmost importance in mine warfare, and therefore the miners should be thoroughly practised at it. Miners inexperienced in such warfare are usually apt to under-estimate the distance of the enemy. Frequently this want of practice added to the excitement and interest which the miners feel more and more as they approach the enemy, leads to premature explosions, or to misfires. To accustom officers as well as men to look at matters calmly and coolly, they should be made to understand, in the work of the practice-ground, that it is much better to come into actual collision with the enemy's miner than to produce an explosion without being satisfied that the enemy's distance is less than the length of the line of least resistance.

"With the same object it is well to take care that, during the establishment of the countermine system, the miners pay attention to the sounds of work in the galleries adjacent to them, and especially in the portions of transversals which are advancing towards

each other; and the distances so estimated by the ear should be carefully verified by the working plan.

"The two leading considerations for the besieged are:—

"1. To endeavour to destroy the enemy's galleries as extensively as possible.

"2. To avoid making craters of any considerable depth on the surface of the ground.

"Consequently the besieged should establish his countermines at such depths that even if he uses large charges they may not produce craters. And to destroy the greatest possible length of the besieger's galleries the besieged should not fire his mines until the enemy's distance from him is less than the line of least resistance.

"In that case he may, without fear of making too deep craters, increase his charges up to one-and-a-half times, or even twice, the charge of a camouflet, reckoned as the charge for a common mine, but taking only four-sevenths* of the line of least resistance; for the charge will produce most of its effect in the enemy's gallery, and its action on the surface will be insignificant. It is only when the ground has been much shaken by previous explosions that a smaller charge must be used.

"Besides, even if a shallow crater is made, the besieged may occupy it, if circumstances are in their favour, taking care to cut away its slope on the side of the fortress sufficiently to allow their artillery to search the interior of it. Or if the besieged should not succeed in getting possession of the crater, or, having made a lodgment, should be driven out of it, it will be a very difficult matter for the besieger to hold his ground there, so close to the works of the place; for, so long as the place can still mount any artillery, the crater will always serve as their target.

"Throughout the mine warfare the besieged should avoid premature explosions, to which he will be tempted by a fear that the attack will anticipate him. Repeated instances, alike in war and in peace, make it quite certain that such apprehensions have always been unfounded. The miner who acts with coolness and wise circumspection will never have reason to repent it.

"This is proved by the fact that the counterminer who fires a mine when the distance of the enemy's gallery is greater than the line of least resistance, succeeds only in damaging his own branch, and making a crater, without doing any serious harm to the

* One-half, according to the English rule.

besieger. So that the besieged is actually in a worse position than he was before he fired his mine; for, obliged to fall back several yards, he will leave the besieger free to prepare an overcharged mine, or to sink a 'Boule' shaft in the crater he has made.

"After two or three successive explosions in the same branch, much of it will necessarily be injured. On this account, and in order not to be driven back at this point, it is well for the besieged to provide himself, while there is yet time, with a reserve branch, placed at a small distance from the injured branch.

"After the besieger has fired his overcharged mines the besieged should:—

"1. Hinder the enemy from occupying the craters, by a violent fire of grape and musketry. But if he nevertheless takes possession of them, a continuous fire from mortars must be directed on the craters; while by the fire of guns the making of any communication above ground should be stopped, so as to prevent the assailant from solidly establishing himself in the craters, and resuming his mines.

"2. Push forward at once by his branches, introducing himself under the actual slope of the craters, and embracing them in front and on the flanks.

"The branches must be disposed at minimum intervals apart, so that the besieger may not be able to pass between them without receiving a camouflet.

"3. Produce explosions inside the craters, supposing that the besieged has been successful in arresting every attempt of the besieger to open new galleries in the bottom of the craters.

"'Boule' shafts being very dangerous for the countermines, the besieged should do his best to oppose their formation, above ground by artillery and musketry fire, and underground by camouflets, striking the besieger through holes bored for that purpose. Further, he must take advantage of every favourable opportunity to delay the progress of the siege works by sorties from the place.

"Such are the principal rules to be drawn from the practice acquired during the siege of Sebastopol, and during previous sieges. The observance of these rules is a necessary condition to secure a favorable issue in a war of mines. At the same time it is to be remarked that each particular case may present exceptional circumstances, and that success in mine warfare will always depend, not only on the observance of these general rules, but also, and even more, on the miner's power of weighing all such circumstances, and his skill in turning them to the best account."

E. M. L.

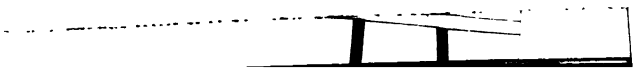
EXPLOSIONS.

Date.	RUSSIAN. No.	RUSSIAN. Pounds.	FRENCH. No.	FRENCH. Pounds.
February 3rd	1	433	—	—
„ 7th	—	—	1	407
„ 9th	2	324	—	—
„ 26th	—	—	2	154
March 2nd	3	108	—	—
„ 3rd	4	433	—	—
„ „	5	541	—	—
„ 5th	6	541	—	—
„ „	7	541	—	—
„ 7th	8	433	—	—
„ 10th	9	433	—	—
„ 15th	10	433	—	—
„ 23rd	11	433	—	—
April 7th	—	—	3	198
„ 12th	12	757	—	—
„ 15th	—	—	4	1,254
„ „	—	—	5	1,254
„ „	—	—	6	2,508
„ „	—	—	7	2,508
„ „	—	—	8	2,508
„ „	—	—	9	2,508
„ „	—	—	10	2,508
„ „	—	—	11	4,180
„ „	—	—	12	4,180
„ „	—	—	13	4,180
„ „	—	—	14	4,180
„ „	—	—	15	2,508
„ „	—	—	16	2,508
„ „	—	—	17	1,254
„ „	—	—	18	1,254
„ 22nd	—	—	19	4,180
„ „	—	—	20	2,508
„ 23rd	—	—	21	4,180
„ „	—	—	22	2,508
„ „	—	—	23	2,508
„ 24th	13	433	—	—
„ „	14	433	—	—
„ „	15	433	—	—

Date.	RUSSIAN. No.	Pounds.	FRENCH. No.	Pounds.
April 25th	16	433	—	—
„ 28th	—	—	24	418
„ 30th	17	324	—	—
„ „	18	433	—	—
May 1st	19	433	—	—
„ „	20	324	—	—
„ „	21	324	—	—
„ „	22	433	—	—
„ „	23	324	—	—
„ 2nd	24	324	—	—
„ „	25	433	—	—
„ 3rd	—	—	25	1,672
„ „	—	—	26	2,508
„ 12th	—	—	27	836
„ 14th	26	216	28	418
„ 15th	—	—	29	460
„ „	27	216	30	836
„ 16th	28	216	31	836
„ 17th	—	—	32	836
„ 18th	29	324	—	—
„ „	30	216	—	—
„ 19th	—	—	33	836
„ „	—	—	34	836
„ 24th	—	—	35	418
„ 27th	31	216	36	585
„ „	—	—	37	877
„ 28th	32	216	38	125
„ „	—	—	39	627
„ 31st	—	—	40	836
„ „	—	—	41	418
„ „	—	—	42	418
June 3rd	—	—	43	418
„ „	—	—	44	594
„ 4th	33	216	45	418
„ „	34	216	—	—
„ 5th	35	216	46	752
„ „	—	—	47	836
„ „	—	—	48	502
„ 6th	36	216	—	—

Date.	RUSSIAN. No.	RUSSIAN. Pounds.	FRENCH. No.	FRENCH. Pounds.
June 9th	—	—	49	836
„ 11th	—	—	50	669
„ 12th	—	—	51	460
„ 13th	37	108	—	—
„ 15th	—	—	52	460
„ 19th	—	—	53	627
„ 20th	—	—	54	627
„ 21st	38	216	—	—
„ „	39	108	—	—
„ 22nd	—	—	55	418
„ „	—	—	56	460
„ 24th	40	216	57	1,087
„ 25th	41	216	—	—
„ 26th	42	216	58	502
„ 28th	—	—	59	2,508
„ „	—	—	60	2,508
„ 29th	—	—	61	1,254
July 7th	43	216	—	—
„ 8th	—	—	62	627
„ 10th	44	216	—	—
„ 11th	45	216	—	—
„ 12th	46	216	—	—
„ „	47	216	—	—
„ 14th	—	—	63	634
„ „	—	—	64	634
„ 15th	—	—	65	634
„ 16th	48	216	66	502
„ 17th	49	216	—	—
„ 18th	—	—	67	334
„ „	—	—	68	334
„ 20th	—	—	69	836
„ 21st	—	—	70	627
„ 22nd	50	108	71	627
„ „	—	—	72	627
„ 24th	—	—	73	627
„ 26th	51	216	—	—
„ 27th	—	—	74	627
„ 28th	52	216	—	—
„ 29th	—	—	75	2,800

Date.	RUSSIAN. No.	RUSSIAN. Pounds.	FRENCH. No.	FRENCH. Pounds.
July 29th	—	—	76	2,926
„ 30th	—	—	77	1,086
„ 31st	53	216	—	—
August 1st	54	216	—	—
„ 2nd	—	—	78	2,508
„ „	—	—	79	836
„ „	—	—	80	418
„ 3rd	55	216	—	—
„ „	56	108	81	502
„ 4th	57	108	—	—
„ 5th	58	108	—	—
„ 7th	59	216	—	—
„ 8th	60	216	82	627
„ „	—	—	83	627
„ 9th	61	216	84	627
„ 11th	—	—	85	585
„ „	—	—	86	585
„ 12th	—	—	87	627
„ „	—	—	88	502
„ 13th	—	—	89	836
„ 14th	62	216	90	627
„ „	63	216	—	—
„ 15th	64	432	91	752
„ „	65	216	92	752
„ 16th	—	—	93	502
„ 18th	66	216	—	—
„ 20th	—	—	94	2,508
„ 21st	67	432	—	—
„ 22nd	68	216	—	—
„ 23rd	69	216	—	—
„ 24th	70	324	—	—
„ „	71	324	—	—
„ 25th	—	—	95	836
„ „	—	—	96	627
„ 26th	—	—	97	2,090
„ 27th	72	253	98	627
„ „	73	324	—	—
„ „	74	324	—	—
„ 28th	75	216	—	—



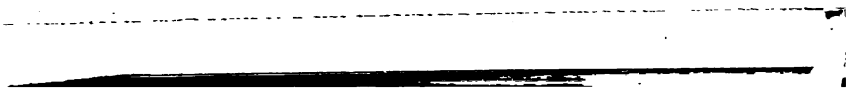
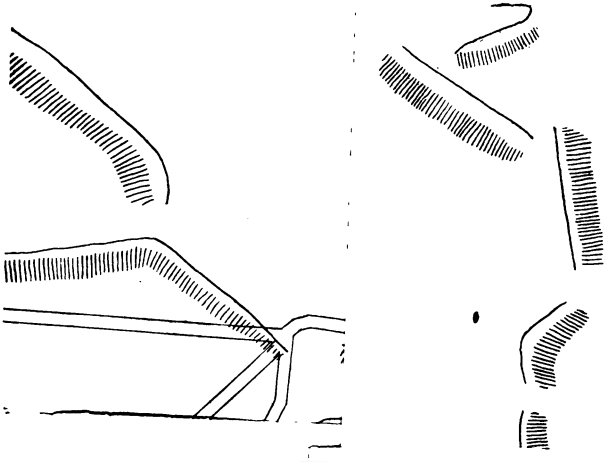
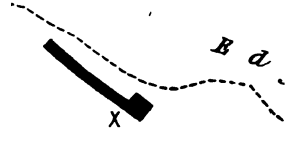


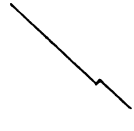
Plate 4.



TERMINES.

----- *Red*.
-- *Blue*.





XIII
XII

Date.	RUSSIAN. No.	RUSSIAN. Pounds.	FRENCH. No.	FRENCH. Pounds.
August 28th	76	180	—	—
„ 30th	77	216	—	—
„ „	78	180	—	—
September 1st	79	108	—	—
„ 2nd	—	—	99	627
„ „	—	—	100	1,254
„ „	—	—	101	1,254
„ 3rd	80	216	102	1,254
„ „	—	—	103	1,045
„ „	—	—	104	1,045
„ 4th	81	108	106	1,254
„ „	82	216	107	1,626
„ 5th	83	216	—	—
		23,095		131,734

N.B.—The above table is taken from the Russian account. There are some discrepancies between that and the French account as regards the number of the Russian explosions.

PAPER XI.

A BRIEF SKETCH OF THE PRESENT STATE

OF

BRITISH GUNNERY.

By Major Eardley Maitland, R.A.

A Lecture delivered at the R.E. Institute, on 31st July, 1877,

The last three or four years have witnessed remarkable progress in the science of Artillery, not only in our own country, but among nearly all the continental nations, and it would be quite impossible to convey to an ordinary audience in one short lecture any adequate idea of the advance which has taken place all along the line. Fortunately, those now present have already been thoroughly grounded in the subject of gunnery, and I will therefore assume that all are conversant with general principles, and if in the endeavour to compress, and to avoid unnecessary detail, I become obscure, perhaps I may be kindly permitted to answer any questions that you may wish to put after the lecture is over.

As time is short I omit all reference to the old smooth bored ordnance, and plunge at once into the subject of rifled guns, dividing it into two parts:—

1st. The guns we could bring against the enemy if we were to go to war to morrow.

2nd. The guns we hope to introduce into the service as soon as preliminary experiments are brought to a close.

I have prepared two tables giving certain particulars of the weights, power, and employment of the rifled ordnance in our

services. Table A includes all the principal guns in the land service. Table B shows those in the sea service.

It has always been an object with the authorities to assimilate the guns of the two services as far as their respective requirements will permit, and so to avoid multiplication of stores at the numerous home and foreign stations where supplies are made; but still it will be observed that considerable differences exist, and judging from the progress of events, it appears that these differences will increase, because as the science of gunnery becomes developed, each new kind of gun is more exactly fitted to the performance of the special work for which it is intended, and therefore less suitable for other purposes; as an illustration of my meaning the history of the muzzle loading 9-pr. of 8 cwt., may be adduced; this gun was originally intended for, and issued to, the Horse Artillery and field batteries, and was a few years ago the most powerful piece of its size in the world; thereupon the navy adopted it as a boat gun. Improvements were made; other nations found it possible to obtain equal power with lighter guns. Our field 8 cwt. gun was replaced by a 9-pr. 6 cwt. gun using precisely the same ammunition; all the land service 8 cwt. 9-prs were practically superseded; the recoil of the lighter gun was of course considerably more violent than that of the heavier, but the field carriages were improved and strengthened so as to obviate the difficulty arising from this cause; with the boats the case was different, the recoil proved objectionable, and as the additional weight of two cwt. is of much less consequence in a boat than behind a team of horses, it was determined to use all the land service 9-prs. of 8 cwt. for boats. Thereupon the land service discovered that though 6 cwt. was perhaps better than 8 cwt. for Horse Artillery, yet that if a considerable increase of power could be obtained by adding the two cwt., the field batteries could well manage to draw it; and accordingly a 12-pr. of 8 cwt. was designed, and is now in process of introduction; I shall describe it farther on, and will only say now that it is by far the most powerful weapon in the world of its kind. This short history shows that the theory of evolution in a Darwinian sense applies to guns as well as to organic beings.

Table A shows five distinct classes of rifled ordnance; we will take them in order.

You have all seen the several ways in which the *heavy armour piercing guns* are mounted round our coasts, and as you construct

TABLE A. *LAND SERVICE RIFLED GUNS.* *July, 1877.*

Nature, Weight, Calibre, &c.	Weight of heaviest Projectile.	Max. Service Muzzle Velocity.	Class.	Perforation at 1,000 yds. About	Bursting charge of com. shell—about	How Mounted.	Remarks.
Muzzle Loading.	lb.	f.s.		ins.	lb. oz.		
12″·5 of 38 tons.	800	1420	Armour piercing guns.	.....16·0.....	50 0	In casemates, on sliding carriage on traversing platform on racers.	Experiments still in progress.
12″·0 of 35 tons.	700	1340		.....13·7.....	40 0	Barbette only on ditto ditto.	Very few of these guns exist. Common shell 618. lb.
12″·0 of 25 tons.	600	1300		.....10·8.....	38 0	In casemates on do., and en barbette.	Ditto. Com. shell 495 lb.
11″·0 of 25 tons.	535	1315		.....11·9.....	30 0	Do. Do. Do.	Experiments still in progress.
10″·0 of 18 tons.	400	1365		.....11·2.....	20 0	Do. Do. Do.	
9″·0 of 12 tons.	250	1420		..... 8·8.....	19 0	Do. Do. Do.	
7″·0 of 7 tons.	115	1560	Land front (fortress) guns.	Armour piercing projectiles not supplied for these and smaller guns.	9 0	En barbette, sliding carriages on traversing platfrm. Moncrieff carriages.	Double shell, 160 lb.
7″·0 of 82 cwt., breech loading.	90	1165			6 0	Do. Do.	
80-pr. (6″·3) 5 tons.	80	1240			9 0	Sliding carrs. on traversing platform.	
64-pr. (6″·3) 71 cwt. & 58 cwt.	64	1230 1245			7 0	Standing and Moncrieff carriages.	Converted from 8″ s.b. gun and 32 pr. s.b. gun.
64-pr. (6″·3) 64 cwt.*	90	1365	Siege Train guns.	23 to 25ft. from point of shaft to muzzle of gun.	7 0	Travelling carriages (siege).	Common shell, 64 lb.
40-pr. (4″·75) 35 cwt.	40	1360			3 0	Do. (siege & batteries of position).	
25-pr. (4″·0) 18 cwt.	25	1320			2 0	Do. Do.	
8″·0 howr. 46 cwt.	180	790			14 0	Travelling carriages (siege); also on beds for siege.	
6″·3 howr. 18 cwt.	64	830			7 0	Travelling carriages (siege).	Experiments in progress.
16-pr. (3″·6) 12 cwt.	16	1355	Field guns.	About 23ft. from point of shaft to muzzle of gun.	1 2	Field gun carriages, with limbers.	Shrapnel 18·5 lb.
9-pr. (3″·0) 6 cwt.	9	1390			0 7	Do. Do.	
7-pr. (3″·0) 200 lb.	7	970	Mountain Train guns.	.....	0 6	Mountain service,—on travelling carriages. Siege,—on beds.	Double shell, 12 lb.
7-pr. (3″·0) 150 lb.	7	675		.....	0 6	Do. Do.	Do.

* Special projectiles for penetrating masonry.

TABLE B. *SEA SERVICE RIFLED GUNS.* *July, 1877.*

Nature, Weight, Calibre.	Weight of heaviest Projectile.	Max. Service Muzzle Velocity.	Perforation at 1,000 yds. About	Bursting charge of com. shell—about	How Mounted.	Remarks.
Muzzle Loading.	lb.	f. s.	ins.	lb. oz.		
12″·5 of 38 tons.	800	1420	.....16·0.....	50 0	In turrets, loading by hydraulic machinery.	Experiments still in progress.
12″·0 of 35 tons.	700	1340	.....13·7.....	40 0	In turrets, loading by hand gear.	Very few of these guns exist. Common shell, 618 lbs.
12″·0 of 25 tons.	600	1300	.....10·8.....	38 0	Do. do., and broadside.	Very few of these guns exist. Common shell, 495 lbs.
11″·0 of 25 tons.	535	1315	.....11·9.....	30 0	Broadside, revolving, and on turntable *en barbette.*	Just introduced for Navy. Experiments in progress.
10″·0 of 18 tons.	400	1363	.....11·2.....	20 0	Broadside, revolving, in turrets, and in gunboats.	
9″·0 of 12 tons.	250	1420	..... 8.8.....	19 0	Broadside and revolving.	
8″·0 of 9 tons.	180	1415	..... 7.7.....	14 0	Broadside.	
			Armour piercing projectiles not used for guns of less than 8″ calibre.			
7″·0 of 6½ tons.	115	1525		9 0	Broadside.	Double shell, 160 lbs.
7″·0 of 90 cwt.	115	1525		9 0	Broadside.	Do. do. Experiments in progress.
64-pr. (6″·3) of 64 cwt.	64	1385	.....	7 0	Broadside.	
64-pr. (6″·3) of 71 cwt.	64	1230	.....	7 0	Broadside.	Converted from 8″smooth-bored shell gun
9-pr. (3″·0) of 8 cwt.	9	1380	.....	0 7	Boat.	
9-pr. (3″·0) of 6 cwt.	9	1235	.....	0 7	Boat.	
7-pr. (3″·0) of 200 lb.	7	970	.....	0 6	Boat.	Double shell, 12 lbs.
Breech loading.						
20-pr. (3″·75) of 13 cwt.	21	1000	.....	1 2	Gun vessel and upper decks of ironclads against torpedo vessels.	
12-pr. (3″·0) of 8 cwt.	12	1170	.....	0 8	Boat—nearly obsolete.	
9-pr. (3″·0) of 6 cwt.	9	1060	.....	0 6	Do.	

the casemates, barbette batteries, &c., for us, and no doubt are thoroughly familiar with the subject from an engineering point of view, I will merely mention that while the artilleryman quite appreciates the comfort of being made as safe as possible, he is also desirous of inflicting the maximum amount of damage upon the enemy. To do this it is absolutely essential that he should be able to lay his gun with accuracy and rapidity; and here he wants your help in several points. You must provide a good look-out place, more especially with the new system of firing at objects in motion unseen by the gunners. You must provide for the rapid supply of cartridges and projectiles, so that a swift steam vessel may not get past unmolested. Supposing a gun to train through an angle of 50°, and a vessel 1,000 yards off to be steaming at 12 knots, it will take barely two minutes and a half to get by. Evidently it is of the utmost importance to be able to get a second shot. Having loaded in time, in order to hit, we must have the racers true, and I trust I shall be forgiven if I make a great point of this. I know it is a matter of difficulty to lay a racer true, firm, and solid; but it really must be done if we are to make decent practice. It is not only that a depression in the racer allows one truck to sink, and so throws out the line, but, worse than this, it renders it impossible to get the gun into line at all, unless the bottom of the indent happens to be exactly in the right place. No amount of scotching up will ensure accuracy of direction if the depression is a bad one; directly the recoil begins, before the shot has left the muzzle, a shift takes place, and the aim is spoiled.

Turning to the guns with which the *land fronts* of our fortified places are armed, it will be seen that, with the exception of the 7-inch muzzle loading gun, they are all somewhat less powerful than the most effective of the siege train guns. I believe, and hope, that a proportion of 9-inch guns will, before long, be provided for our land fronts, as otherwise we certainly fail to utilize the full advantage to be derived from a position fortified and armed at leisure.

A large number of 7-inch breech-loading guns has recently been put in order, and told off to the Portsmouth forts. Most of our strong places are still armed largely with the old smooth bores, and there is no doubt that this portion of our equipment is less advanced than any other; such will necessarily be the case as long as an invasion of England is regarded as a danger of a somewhat visionary character; long may it remain so.

With regard to the *siege trains*, I must refer those specially interested in this part of my subject to the forthcoming report of the Siege Operation Committee—a report which I feel sure will deal with the various branches of the question in a comprehensive and exhaustive manner. There are, however, a few remarks which I should like to make while I have the opportunity. You see (Table A) we have in the siege train nothing heavier than 64 cwt. This is the maximum weight which it is considered can be dragged over a favourable country, while the 35 cwt. gun is intended to take the place of the heavier one when the country is unfavourable. In our old wars it was always considered that if the fortress possessed guns equal, or at any rate slightly superior to the enemy's siege train, all was done that could be done. Tradition has great vitality in the army, and we have, I think, scarcely yet learned to appreciate the enormous change which has taken place in the facilities for transport in civilized countries, nor have we yet yielded to the conviction that it is impossible to possess too powerful artillery—that a crushing superiority is the cheapest defence.

The siege train is all very well for the attack of out of the way places, but in Europe nearly every city of importance has many railroads converging on it. If these are in the hands of the besieger he can bring up guns far more powerful than 64-pounders. If we were to attack Sebastopol again now, I make no doubt that we could run up a line to carry 9″, or even 10″ guns, and place them in position; and those who build and arm fortresses must be prepared for this.

The 25-pounder guns of 18 cwt. are intended for the siege train in difficult countries, or in India. They will also, no doubt, be used as guns of position, and perhaps in time as heavy field guns. The 8″ howitzers carry a heavy shell, and are intended for use either as mortars or howitzers. They can be fired either on their travelling carriages or on the ground, as the body of the carriage, when the wheels are removed, forms a convenient bed. The 6″·3 howitzers are intended to perform similar duties.

The siege train guns are grouped into two classes. A unit of the heavy train comprises:—

64-pounders of 64 cwt.	...	...	...	8
40 „ of 35 „	...	...	...	8
8″ howitzers of 46 „	...	...	...	14

A unit of the light train comprises:—

40-pounders of 35 cwt.	...	...	10
25 „ of 18 „	...	...	10
6″·3 howitzers of 18 „	...	...	10

and each unit is completed in every respect with its own stores, spare parts, repairing implements, &c.

With regard to the two natures of *field guns*, which are very much like one another except in weight, I need only remark that it is quite time that their power and range should be fully recognized. The army at large has an idea, derived from the exploits of smooth-bored artillery, that field guns cannot do much at ranges over 1,200 yards. This is a very great mistake, and the Okehampton experiments have, I think, done a good deal to correct it; indeed some enthusiastic gunners, on the strength of these trials, would vaunt the prowess of the 16 and 9-pounders as extending to 4,000 yards. Without, however, quite subscribing to this estimate, I think there is no doubt whatever that the 9-pounder will inflict much injury on troops up to 2,500 yards, and 16-pounders up to 3,000; so much so indeed that a column would scarcely be able to show itself at those distances without serious loss.

The *mountain train guns* are both 7-pounders; they fire the same shell, but the heavier one uses a 12-oz. cartridge, while 6-oz. is as much as can be fired from the lighter one. Both guns are intended for mule transport, one mule taking the gun, another the carriage: but at the Cape of Good Hope the heavier 7-pounder is mounted on a light high field carriage for transport as well as for firing, while in Ashanti the lighter 7-pounders were dragged on a kind of sleigh. The lighter gun is tolerably effective for nearly a mile, and the heavier for about a mile and a half.

Turning now to Table B, in which the principal sea service rifled guns are shown, it will be evident that there are three kinds of work to be performed by them, viz., to pierce ironclads and armoured forts; to attack unarmoured vessels; and to keep up a fire on troops on shore, or on approaching boats. The heavy armour piercing guns are well provided with common shell as well as with chilled projectiles, so as to perform the first and second duties, but they have a very small proportion of shrapnel shell, which is intended to be used by them against troops or boats only on emergency. The 7″ and 64-pounder guns are supposed to be quite sufficient in ordinary cases for the second and third duties, assisted in the third case

by the smaller boat guns. All these are well furnished with common shell and shrapnel.

It might often happen that excellent service would be done by naval guns landed and placed in defence of some fortification or field work. Such employment would be merely a question of transport, as the naval carriages are, of course, not designed for locomotion, except in a few cases, where the blue-jackets are taught to land and manœuvre a regular field battery, *minus* the horses.

I have now given you a hasty outline of the kinds of guns we could bring against the enemy at once, together with a sketch of the general principles which would guide their employment on service. Progress makes, however, such rapid strides nowadays, that much of what you have on Tables A and B may shortly be altered, and in order that approaching changes may be intelligible to you, it seems desirable to make a few remarks on the character of the gunnery experiments now in progress.

With very heavy guns the chief object is to drive a projectile through the thickest armour at a fighting range.

With medium guns, shell power is the prime object.

With small guns, everything must be sacrificed to efficiency of shrapnel fire.

For heavy guns, the striking energy of the projectile must be as great as possible, as compared with the size of the hole to be made. Taking the weight of the shot of any calibre as fixed, we require then the highest attainable velocity. At the same time we have to fire very many rounds from the gun, which should be as light as is consistent with safety and manageability. Hence, briefly, we want the ratio of muzzle velocity of shot to breech pressure of gas to be as high as possible, and for some years the principal efforts of artillerists have been directed to this end. In 1869 we were obtaining with our heavy guns (10″ & 12″) muzzle velocities of about 1200 feet per second, with powder pressures at the breech measuring 40, or even 50, tons on the square inch. These pressures were local, it is true, and lasted but a very brief time; otherwise no guns could have sustained them. Still, they were highly injurious to both gun and projectile. We are now beginning to get velocities with similarly proportioned projectiles from our heaviest ordance of 1600 feet per second, while the pressures do not exceed 20 or 21 tons. Several important improvements have combined to bring about this advance. They all arise from the acquisi-

tion of a more perfect knowledge of the action of the powder gas inside a gun, and the principal ones are three in number.

First, a great stride was made in the manufacture of powder when pebbles—and subsequently $1\frac{1}{2}''$ cubes—were introduced.

Second, the discovery of the beneficial effect of *chambering*, that is, of boring out the powder chamber to a greater diameter than that of the rest of the bore.

Third, the method of adjusting the cartridge so that a certain weight of powder should have a certain definite space allotted to it, the amount being determined by experiment, and being irrespective of the actual volume of the powder grains. Thus, in the 80-ton gun, powder cubes of $1\frac{1}{2}''$ edge were used, their absolute density being a little over 1·75, or about 15·7 cubic inches per pound. When these grains were rammed tightly home in a serge bag, the space occupied behind the shot was 24·6 cubic inches per pound; as actually used for practice a vacant space over and within the cartridge was left, so that the space behind the shot amounted to 34 cubic inches per pound.

I will now describe, as well as I can, the action that takes place in the bore of a gun when the flame reaches the cartridge. It is not very easy to convey an adequate impression of it, and I must ask your patience. If I am successful in making it clear, the *rationale* of the three improvements just enumerated will become clear also, and probably you will wonder why they were not carried out long ago.

Suppose the cartridge to consist of ordinary powder grains, rammed up as tightly as they will conveniently bear (R.L.G. powder, 28 cubic inches per pound; pebble, 26; $1\frac{1}{2}''$ cubes, 24·6). and the flame to be applied to one end. And here I must remind you that gunpowder is not properly an explosive, but a substance which burns (and gives off its gas) with great rapidity. It cannot, as far as is yet known, be detonated, but simply burns down from the outside surface to the heart of the grain, which is thus gradually converted into gaseous and liquid products. We have now got to the application of flame at one end of a cartridge; the nearest grains then ignite, and their surfaces rapidly evolve gas in a state of violent incandescence. This gas travels with great velocity through the interstices between the grains composing the rest of the charge, lights them in passing, and is continually augmented in volume by their gas, the combination gaining velocity as it pro-

ceeds, till, arriving at the farther end of the cartridge, it receives a check, and applies a pressure with great suddenness; this pressure is often called a blow. It immediately reacts on the now greatly increased quantity of gas evolved behind, and, when excessive, results in those abnormal indications registered by the crusher gauges, and spoken of by artillerists as "wave pressures." These wave pressures are dynamical, and the records given by them greatly exceed those of the steady pressure given even by charges in closed vessels. I have not time to describe the instruments used to ascertain these particulars, but an excellent description of them, by Captain Jones, R.A., will be found in Vol. IX. of the "R.A. Institution Proceedings." As one illustration, I may mention that if a cartridge of quick-burning powder, rammed tightly, and having a length of about three times its thickness, be lighted at one end, and if pressure gauges be placed in the walls of the gun—one at each end of the charge, and one over the middle—those at the ends will usually register about double the pressure per square inch that will be indicated by the centre one.

I have specified a "quick burning" powder; by that term is meant a powder the grain of which is small in proportion to the calibre of the gun. All our gunpowders, from the old *poudre brutale* L.G. to the large cubical $1\frac{1}{2}''$ powders of the present day, are made of the same ingredients combined in the same proportions, they vary only in density and in size of grain. Turning back for a moment to the action of the lighted gas evolved from the first ignited grains, and rushing through the cartridge, lighting up all the grain surfaces it meets with, it becomes at once evident that the larger the grains of powder are the less will be the surface thus lighted up; of course, if you take a cube of $1\frac{1}{2}''$ edge, and break it up small, you have not only the original surface but a number of fresh surfaces, and as all these will be simultaneously lighted, the whole quantity will take a much shorter time to be consumed than when the cube was entire. Thus, other things being equal, a small grain powder is a quick burning powder.

You now grasp at once the effect of enlarging the grains; the action is rendered less violent, its intensity is dulled, as it were; the wave pressures which are practically useless in the production of velocity are got rid of, and the maximum statical pressure is lowered also by another circumstance which we must now take into account.

The old writers on gunnery were accustomed to consider that all

the powder was converted into gas before the shot had sensibly moved, and with the violent powders in use in their day there was probably no great error in their assumption, which was a convenient one as it simplified calculation. If it were a true assumption the full pressure of the gas would be set up before the shot started, and we should always have pressures of about 38 tons on the square inch, that being the pressure observed by Captain A. Noble, of Elswick, in his experiments with powder exploded in closed vessels, the density of the charge being that of water, (27·7 cubic inches per pound).

Supposing a gun to be pointed vertically upwards, so that the full weight of the shot has to be raised by the gas, it is obvious that the longer the shot the greater weight there will be on each square inch of base. The shot of the 80-ton gun is the longest we have got, it weighs 1,700 lbs., and is 16 inches in diameter, this gives $8\frac{1}{2}$ lb. for each square inch of base; that is, directly a pressure of $8\frac{1}{2}$ lb. per square inch is exerted by the gas the shot must begin to move, even when the gun points to the zenith. As the maximum pressure, a steady uniform pressure be it remembered, amounts to about 20 tons, it is abundantly clear that the shot must have got under way at some period antecedent to the setting up of the maximum pressure; and not only must this be the case, but as the moving away of the shot leaves an increased space behind it in which the gas expands, the maximum pressure never reaches the normal 38 tons just mentioned; and the question resolves itself into a race between the powder and the shot, the powder trying to increase the pressure by giving off its gas, and the shot trying to reduce the pressure by leaving more room for the gas to expand in; at first the powder appears to be gaining till the maximum pressure is attained, but the shot "stays" the longest, and eventually wins. Where moderate charges of R.L.G. powder are employed in heavy guns, the shot has usually moved about one inch by the time the maximum pressure is set up; with pebble powder about 4 inches; with $1\frac{1}{2}$ inch cubes about 6 inches; and probably when the cartridges are air-spaced to 34 cubic inches per pound, the maximum pressure scarcely falls till the shot has moved about a foot.

As it is the maximum pressure which is most likely to strain or injure the gun and projectile, it is desired to keep this maximum pressure as low as possible, and to sustain it as long a time as possible, so as to impart the greatest velocity to the projectile; thus the ideal of the artillerist would be a charge so arranged that a

pressure equal to the amount the gun is constructed to bear should be uniformly maintained till the shot has left the muzzle. We are a long way from this, but still a good deal has been done towards it in the last 7 or 8 years.

The effect of chambering out the end of the bore where the powder lies is practically to permit a small gun to burn effectively the charge of a larger one. The cartridge is shortened and the mechanical conditions of burning are greatly improved. Thus in experiments with a 9-pounder gun, service bore and service powder, it was found that by gradually increasing the charge a gain in velocity was obtained up to $2\frac{1}{2}$ lb. (service charge = $1\frac{3}{4}$ lb.), but that farther increase up to $2\frac{3}{4}$ lb. and 3 lb. gave no additional velocity. When the chamber was enlarged from 3″·0 (service bore) to 3″·6, the velocity continued to rise with the charge, till with 3 lb. cartridges the chambered gun gave an increase of more than 100 feet per second over the unchambered one, while the pressures were about 30 per cent. lower with the chambered gun than with the other. Also with $3\frac{1}{2}$ lb. in a 3″·8 chamber a velocity of about another 100 feet was obtained, the pressures still remaining moderate.

The amount of air-spacing most suitable for our heavy guns appears to be regulated by the weight of the column of shot on a square inch of base, since the inertia and rate at which the shot acquires velocity depend on this. Thus with $1\frac{1}{2}$″ powder for a 10″ projectile of 400 lb. the best density of the charge has been found by experiment to be about 28 cubic inches per pound; with the 12″·5 of 800 lb. about 30 cubic inches; and with the 16″ of 1,700 lb. about 34 cubic inches. The effect of decreasing the density of the charge is of course to diminish the maximum pressure. Thus while Captain A. Noble found that 38 tons on the square inch was the pressure in a closed vessel, when the ignited powder was at a density of 1·0 (*i.e* = water), he found that at a density of 0·8 (34 cubic inches per pound) the pressure was but 25 tons on the square inch. We are thus enabled to increase the charge of powder, and to provide an additional store of gas which comes into play as the shot passes up the bore, and so sustains the lowered maximum pressure for a longer time.

Thus we make some approach to the artillerist's ideal above mentioned, a moderate uniform pressure throughout the bore.

I have dwelt rather long on this part of my subject, partly

because I feel great difficulty in making it clear, and partly because it is the key to modern progress in gunnery as regards the actual power of the gun with respect to penetration.

For medium guns, shell power, as has been said, is the prime object. I do not think a better illustration of the mode in which a gun is now designed to possess the maximum shell power can be given, than the genesis of the new experimental howitzers, of which you will find particulars in Table C.

The experiments at Eastbourne, as well as oft-repeated trials at Shoeburyness, showed pretty decisively that the howitzers now allotted to the siege train (*vide* Table A) are not all that can be desired with respect to accuracy, and that breaching with curved fire by their aid is a process demanding a larger expenditure of ammunition than can be always conveniently supplied. It was determined, therefore, to take a step in advance, and to produce something which, it was hoped, would more nearly correspond with modern requirements.

A gun is, of course, nothing but a machine, and, like other machines, must be constructed to fulfil certain definite conditions. In the present case these conditions admit of precise solution. For a piece capable of transport over a favourable country on a platform waggon, it was decided that the greatest admissible weight was 70 cwt. The next point is the recoil. The maximum velocities of recoil of the most lively pieces in the service is as follows:—

7-pounder	...	...	32 feet per second.
6″·3 howitzer	...	...	27 „ „
8″·0 „	...	...	28 „ „
64-pounder	...	...	17 „ „

The 7-pounder tumbles head-over-heels frequently, but being small, this is of little consequence; the two howitzers, when fired with their heaviest charges, are very difficult to manage, while the 64-pounder is quite manageable even on a travelling siege carriage. It was, therefore, decided that a maximum velocity of recoil of 20 feet per second might be allowed for the new howitzer. I must explain here that this velocity refers to the motion of the gun only, supposing it to be unchecked. In reality, gun and carriage move back together, and the initial velocity of recoil of the system is much less than the amounts above given. It would not answer, however, to reckon the momentum from this in constructing a gun, as a new variable—the weight of the carriage—would be introduced. We

have now obtained a momentum of 70 cwt., moving at 20 feet per second velocity. Practically, the momentum of the projectile on quitting the muzzle is equal to the momentum of the gun at the same moment. Hence we have 156,800 as the number representing the momentum of our shell. Suppose we took a shell of 100 lbs. weight, we could afford to give it a velocity of 1,568 feet per second. But if we took a shell of 200 lbs. weight, we should find the recoil inconvenient if the muzzle velocity exceeded 784 feet per second.

We now come to a most important condition—what do we want the howitzer to do? The reply is—1st. to breach; 2nd, to bombard. It was then determined that the greatest breaching power required should be obtained at 1,500 yards, at an elevation of 5°. For longer distances, a greater angle would be used, and, of course, all shorter ranges would be covered by this trajectory. We have now a neat problem in ballistics, viz., to find the calibre of a shell about 3 diameters in length, of such a weight that, with the muzzle velocity required to give a range of 1,500 yards at 5° elevation, the muzzle momentum shall be 156,800. By the aid of Professor Bashforth's tables, this problem may be solved with ease, and after a few approximations, it is found that a shell 8″·1 in diameter, weighing 170 lbs., and having a muzzle velocity of 920 feet per second, will fit the conditions. For the sake of round numbers, the calibre is placed at 8″·0, and the first experiments will shortly be carried out to verify the calculations.

For bombarding it was laid down that a range of 5000 yards should be obtainable at 35° elevation; proceeding as before it was found that an 8-inch shell of 230 lb., with a muzzle velocity of 675 feet per second, would be sufficiently near the mark. Lastly, it was found that an 8-inch shell of 170 lb., with a pointed head somewhat approaching the Palliser form, and containing a good bursting charge, would be about $2\frac{3}{4}$ calibres long; and that a common 8-inch shell of 230 lbs., containing a very large bursting charge, would be about $3\frac{1}{2}$ calibres long—results which suit the purposes of breaching and bombarding excellently.

So much for the calibre. We now come to the proportions of the piece. It was at once decided to make the bore as long as possible, consistently with preserving a sufficient amount of metal over the breech to withstand the pressure of the gas. The reasons for this are that less pressure is required to produce a given muzzle velocity, that less strain is thrown on the rotating agent, and that the trunnions are thrown farther forward so that the leverage of the jumping

action is thus lessened; the muzzle portion of the gun was made very strong and thick, partly with the object of advancing the trunnions, and partly because in a siege gun the muzzle is much exposed to the enemy's fire, and should therefore be strengthened, even at the expense of delicacy of appearance.

The 36 cwt. howitzer is constructed on precisely the same principles from data laid down as suitable to a light siege train.

The effect of shrapnel at fighting ranges in the field depends on the construction of the projectile and on the velocity possessed by it at the moment it opens and sets free its bullets. A field battery must carry a large number of rounds on service, and yet must possess great mobility; consequently, the weight of each projectile is rigidly limited. For a given weight of shrapnel, the broad, short form will hold more bullets and possess a better construction than is the case with long, narrow projectiles. It is somewhat easier also to obtain a high muzzle velocity with the larger calibre, at the expense, of course, of increased recoil. But, owing to the resistance of the air, the shrapnel of greater diameter will part with its velocity sooner than the more slender one will, and a maximum of efficiency at a fighting range will be found by a compromise between these two conditions; that is, for a given weight of projectile the calibre must be the smallest that will admit of a thoroughly effective shrapnel. It would never do, for instance, to give up an outer layer of bullets to increase the remaining velocity at burst.

We have only one more question of great importance to consider, and I will not tax your patience long with it.

However powerful our gun may be, as far as its capacity for effectively burning powder is concerned, the damage it does to the enemy will be dependent on the accuracy and efficiency of the projectile. You all know that with muzzle-loading systems the shot have been usually rotated by means of bronze studs let into their walls, while lead coating has been adopted for breech-loading systems. The studs weaken the projectiles; the lead coating is so much weight wasted. In fact, for penetrating purposes, the lead-coated projectiles were found to be about fifteen per cent. less effective than studded ones, other things being equal. The lead-coated shot were however slightly superior in accuracy. Such was the state of affairs up to about two years ago.

Shortly before that time the great wear of the surface of the bore due to the rush of gas over the projectile in muzzle-loading guns,

had led to the adoption of a copper gas check, which is a flanged disc fastened on to the base of the projectile. It has now been found practicable to give rotation by this gas check, and to abolish the studs altogether. The grooves have been reduced in section and multiplied in number, and the tube of the gun is consequently less weakened, while the shot is free from stud holes or lead coating. The escape of gas is altogether stopped by the expansion of the copper disc, which indeed acts more satisfactorily than does the lead coating of the breech-loading systems, where the lands bite into the soft covering.

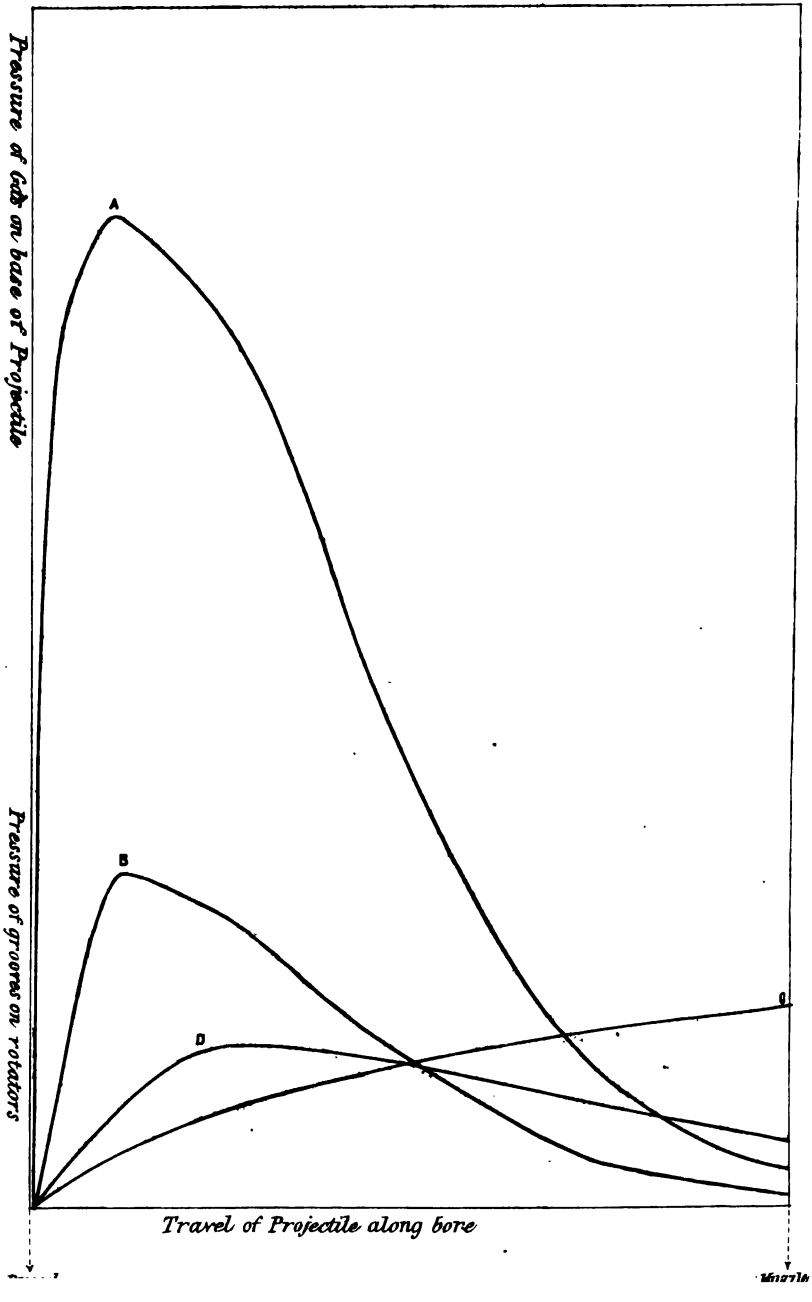
The second 80-ton gun, which has just been tried at Shoeburyness, furnishes the most perfect example of the new rifling which has yet been produced. The bore is 15″·5 in diameter, and has 32 grooves, each 1″·0 broad and 0″·1 deep; the lands are, as nearly as possible, 0″·5 broad. We have, therefore, 32 points in bearing, to give rotation to the projectile. In the early days of rifled guns, attempts were made to give rotation by an expanding base, but they failed, because at that time the uniform twist was universal, and, moreover, a quick powder was employed, so that the gas check had not time to expand and adjust itself to the grooves before it was called upon to perform the arduous task of rotating the projectile, a task the greater part of which has to be accomplished almost immediately when the twist is uniform. By adopting an increasing twist this difficulty is altogether overcome, scarcely any rotation is imparted to the shot till the gas check has fully expanded and settled down to its work. The curve of groove ordinarily employed in our heavy guns is a parabola, whose equation is $y^2 = p\,x$, and the breech end of the rifling is usually the origin—that is, the twist rises from 0 at breech to one turn in a length of from 30 to 50 calibres at the muzzle.

I now draw a diagram showing roughly the pressures on the driving edges of the grooves, and, consequently, on the studs, lead coating, projections on gas check, or whatever gives the rotation.

Curve A shows the nature of the variation of pressure of the gas driving the projectile forward through the bore. I have not put figures, so as to make the curves generally applicable to our slow burning powders. You observe that it rises very rapidly at first, and falls off towards the muzzle. If a quick burning powder were used, the pressure would rise much higher, and more rapidly still at first, falling off more suddenly and completely towards the muzzle.

Curve B shows the result of using a uniform twist. It must be

Diagram of Pressure inside the bore



remembered that curve A represents the pressure on the base of the shot, while curves B, C, and D represent the pressure on the grooves required to do the work of turning the shot. Curve B, bears an invariable relation to curve A; in other words, when the twist is uniform the pressure required to give rotation is a constant function of the pressure driving the shot forward. For simplicity, I have put the function as one-third in the diagram.

Curve C represents the pressures on the grooves when the rifling is of the parabolic form, rising from 0 at the breech. No work is done at first by the grooves, and the maximum strain is much lower than when the uniform twist was employed. This answered very well when the rotation was communicated by studs, but the adoption of an expanding rotator brought some fresh considerations into play. The projections on the gas check are driven into the grooves, and kept up to their work by the pressure of the gas; now, in curve C you observe that the greatest part of the rotation is given as the shot approaches the muzzle; that is, where the projections on the gas check receive least support from the gas. This is obviously wrong, and though with light shot, as in field guns, it may make little matter, yet when we come to heavy shot, about four feet long, turned simply by the base, it is necessary to husband our resources.

It is inadmissible to take the uniform twist which would, of course, make the pressure of rotation exactly fit the driving pressure; because, as I said before, the gas check would not have time to expand before being heavily called upon to do its work We have therefore adopted a curve of groove, called the semi-cubical parabola $\left(y = p\, x^{\frac{3}{2}} \right)$ which rises from O at breech to one turn in fifty cals. at muzzle; curve D exhibits the nature of the pressures on the grooves with this new form of increasing twist, the results of which, so far, have been excellent.

I append a table (C) showing the guns now in the experimental stage, and giving the results which are expected from them should all turn out well. Time will not permit a lengthened description of each, but you will see by the details given that the principles I have been endeavouring to explain are being adopted in all. Chambering is required for the guns where high velocity is a desideratum, but not for the howitzers where low velocities and heavy shell are wanted. The polygroove rifling is coming in for all, except for the 12″·5 guns, of which great numbers are already in the service. Air-spacing will be used for the heavier guns.

TABLE C. *Guns in the Experimental Stage, showing anticipated Results.* *July, 1877.*

Nature, Calibre, and Weight of Gun.	Principal Object to be Attained.	Weight of heaviest Projectile.	Max. Service Muzzle Velocity.	Diam. of Powder chamber.	Weight and Density of Charge.	Rifling.	Perforation at 1000 yds.	Bursting Charge of Com. Shell about;—	Remarks.
Muzzle-loading.		lb.	f.s.	ins.	425 lb., 1¼″ cubes at 34 cub. ins. per lb.	Polygroove. Rotation by gas check. 33 grooves, each 1″ broad. Twist 0 to 1 in 50 cals. Semi-cubical parabola.	ins.	lb.	Experiments nearly concluded, but chambering not yet decided on.
16″·0 of 80 tons.	Perforation of armour.	1700	1630	18·0			28·5	125	
12″ 5 of 38 tons.	Do.	810	1580	14·0	200 lb., 1¼″ cubes at 30 cub. ins. per lb.	Woolwich grooves. Rotation by gas check. 9 grooves, each 1″·5 broad. Twist 0 to 1 in 35 cals. Parabola.	20·7	55	Do. do. Many guns are already issued, and it is doubtful whether studded projectiles (fitted with gas checks) will be continued.
64 pr. of 64 cwt., present calibre 6″·3.	Perforation of masonry & earthwks.	100	1550	6″·3, bore to be 6″·6.	25 lbs., pebble, at 26 or 27 cub. ins. per lb.	Polygroove. Rotation by gas check.			Experiments for increasing the power of these guns recently determined upon.
12 pr. of 8 cwt., calibre 3″·0.	Shrapnel power against troops.	12	1700	3″·6	3 lb., field gun powder, at 27 cub. ins. per lb.	Polygroove. Rotation by gas check. 10 grooves, each 0″·5 broad. Twist 0 to 1 in 30 cals. Parabola.		14 oz.	Experiments nearly concluded. Pattern of shrapnel still undecided.
70 cwt. howr., probable calibre, 8″·0.	Shell power for bombarding.	230	675	Same as bore.	Not fixed.	Polygroove. Rotation by gas check.			Experiments recently determined upon.
	Breaching power.	170	940						
36 cwt. howr., probable calibre, 6″·6.	Shell power for bombarding.	135	610	Do.	Do.	Polygroove. Rotation by gas check.			
	Breaching power.	95	845						

Perhaps it will be said that it would have been more logical for me to have given you an account of the powers of the guns of foreign nations, as it is against them that you will have to construct defences. This is no doubt a true criticism, and I can only plead that the time is too short to permit me to enter upon such a large subject; perhaps also you will pardon the boast if I own to a conviction that if you make your works strong enough to resist our own guns, you need not fear those of other countries.

E. MAITLAND,

July, 1877. MAJOR, R.A.

PAPER XII.

PRÉCIS OF PAPERS

CONCERNING THE INTRODUCTION OF

CAVALRY PIONEERS.

Communicated by the Secretary Royal Engineer Committee.

November, 1876.

Cavalry Pioneers.

Report on the introduction of Pioneers in the British Cavalry.—

The Committee appointed by Adjutant General's letter of 24th November, 1875, to consider the above subject, have made the following report.

Some organization should be adopted, to enable the cavalry to perform efficiently all their important functions in the field.

The duties they may have to perform may be classed under two heads—

(*a.*) *Those necessary in camp*, as shelter in bivouac, field filters, improving water supply, arrangements for watering horses, cutting brushwood for hurdles, fascines &c., making approaches to watering places, &c.

(*b.*) *Those requiring little technical knowledge and but few simple tools*, as shelter trenches, shelter and gun pits, barricades, finding fords, crossing ice, improving roads, making ramps, bridging ditches, cutting telegraphs, delaying use of a railway, destroying bridges, ramps, roads, &c., stopping fords, and tampering with telegraph lines.

There appears to be three modes by which the object sought might be obtained, these are—

(*a.*) By training certain Officers, N.-C. Officers, and troopers, in each cavalry regiment, to perform the duties.

(*b.*) By having mounted sappers to accompany the cavalry,

(c.) By a light engineer train of a few carriages, with some mounted men.

The *first* of these plans is adopted in Austria and Germany, and is being tried in France and Russia. The *second* was partially carried out in the American Civil War. The *third* has not yet been tried to any extent.

Advantages and disadvantages of the above plans—

(*a.*) Regiments with *cavalry pioneers*, though dependent on their own resources, could not execute extensive demolitions. The men would still be effective sabres of their regiments, but there is a danger of their training being neglected.

There is also a danger of the pioneers being withdrawn from their regular duties, when there may be a deficiency of sappers.

(*b.*) *Mounted sappers* could execute demolitions and restorations in a more complete manner, probably, than pioneers.

The sappers not being part of the regiment, would be able to be kept up to their mark by constant practice. Not having to act as cavalry, they could carry more tools than cavalry pioneers.

(*c*) *The light Engineer Train* could execute more extensive demolitions, and make more substantial restorations than pioneers, or mounted sappers. Like the Royal Horse Artillery, they could accompany the cavalry brigade, and the mounted portion could follow the cavalry anywhere. More tools could also be carried by them, and fewer horses would be required for carrying them.

After considering these plans, the Committee decided unanimously that it would be for the good of the service if cavalry pioneers were introduced.

On considering the duties which cavalry pioneers should be instructed to perform, the Committee decided that there should be certain men in each troop, capable of performing the camp duties before mentioned, who should be called *camp pioneers*. All Officers and N.-C. Officers should be acquainted with these duties.

It was also thought advisable to train certain men to perform the regimental duties mentioned in clause *b* above; these men to be called *regimental pioneers*.

Any duties requiring superior skill than the above, are essentially engineers' duties, and have no reference to the cavalry.

The Committee recommended *one N.-C. Officer and four privates* to be chosen in each squadron for *camp* duties, and also *one N.-C. Officer and four privates* in each squadron for *regimental* pioneer duties, (when on *active service.*)

When these pioneers assemble for regimental work they should be under the charge of a specially selected subaltern.

For the peace establishment the Committee recommend that there should be *one N.-C. Officer and two privates* per troop, rated as *regimental pioneers*, and two privates as camp pioneers. These pioneers to be selected from men acquainted with their duties as soldiers, and at least 19 years of age. Privates to cease to be pioneers after 15 years service, or after the age of 33 years.

These pioneers to be taught when with their regiments, but it is recommended that the subaltern, and one N.-C. Officer per troop, be sent for instructions at the S.M.E., Chatham, to obtain certificates from the Commandant as to their efficiency and ability to instruct others.

As soon as a regiment obtains a properly qualified officer, the instruction is to commence, and the officer will give certificates to those privates who qualify as regimental pioneers.

To ensure efficiency and uniformity in the instruction, the Committee recommend an annual inspection by a R.E. Officer.

The pioneers to be similarly armed and accoutred to their comrades, and to have besides, the charge of certain tools.

In order to carry the latter more conveniently, and to lessen the weight, the near horse shoe case to be omitted from the pioneers' saddles.

The Committee proposed the following equipment for the pioneers of each troop.

N.-C.O. carries—

1 leather pouch, with vesuvian match case; 1 holster wallet containing 2″ bull nose screw auger, 16″ long; also wooden detonator holder, containing six detonator's, with 2′ Bickford's fuze attached to each.

1 holster wallet containing auger handle, waterproof bag, and 32 gun cotton discs $1\frac{3}{4}$″ diameter and $\frac{1}{2}$″ thick, 20 yards of No. 22 B.W.G. soft iron wire.

Total additional weight for the N.-C.O., 5lbs. $4\frac{1}{2}$ozs.

No. 1 carries—

15′ of 1″ white lashing rope, and a light helved pick in leather case.

Total additional weight for No. 1, 1lb. 8ozs.

No. 2 carries—

15′ of 1″ white rope, and a cast steel light shovel in leather case,

15′ of 1″ rope, 20 4″ cut nails, and 2lb. hand axe in leather case

Total additional weight for No. 2, 1*lb.* 6*ozs.*

No. 3 *carries*—

Total additional weight for No. 3, 1*lb.* 0½*oz.*

No. 4 *carries*—

2 15′ lashings of 1″ rope, an 18″ hand saw in leather case, a 5″ three square hand saw file with handle, a hand saw set, a 2′ four-fold rule, and pincers or nippers.

Total additional weight for No, 4, 1*lb.* 9½*ozs.*

The *farrier* carries, instead of the felling axe, &c. weighing 7lbs. 13oz., the following articles—

1 holster wallet containing 20 4″ cut nails, a wooden detonator holder, and 6 No. 8 detonators, with 2′ Bickford's fuze attached.

1 holster wallet containing, 1 waterproof bag, 32 gun cotton discs, and 100 yards No. 22 soft iron wire.

Total diminution for the farrier 0*lbs.* 14¾*ozs.*

After considering the explosive to be employed, the Committee rejected *dynamite* as being dangerous, and *wet granular nitrated gun cotton* as being no stronger than ordinary compressed gun cotton.

Compressed gun cotton was selected, in the form of discs, 1¾″ diameter and ½″ thick, weighing 1oz., as capable of producing the best effect.

Each *charge to* consist of 8 *discs*, 4 such charges being carried in a waterproof bag, in a leather case.

A charge of 8oz. will destroy a rail or timber piece.

The discs to be of *dry* gun cotton.

Each detonator to have 2′ of Bickford's fuze attached to it, the end of which should be fitted with quick match, and be covered with a waterproof cap.

For lighting the fuze, vesuvians are to be used.

The *tools selected* to be carried by the pioneers, are the light infantry pick and shovel, weighing respectively 2¾ and 2½lbs.

The 2lb. hand axe to be carried, instead of the 6lb. felling axe now carried by farriers.

Each squadron to carry 6 picks, 12 shovels, 2 spades, 2 felling and 6 hand axes, available for camp and also for regimental pioneer work. An 18″ hand saw, weight 12ozs. to be carried, instead of the ordinary hand saw, weighing 1¾lbs.

The auger to be a 2″ bull nosed screw auger, 16″ long, weighing 2¼lbs. When necessary, the regimental supply of gun cotton, &c., is to be replenished from the R.E. Field Park.

As pioneers would be excused no regimental duties, and would have more work to do than their comrades, some additional pay is recommended.*

A small quantity of gun cotton, &c., to be allowed for instruction, &c.; also that dummy charges be carried in time of peace, though the necessary supplies are to be available when required.

End of Committee's Report, dated 17-2-76.

Simultaneously with the action taken by the above Committee, the Commander-in-Chief in India brought to the notice of the Indian Government, the desirability of a regular pioneer equipment in the Indian army, urging its necessity, and citing the Austrian and other armies as instances.

The objection to pioneer equipment is the extra weight to be carried, but this is counterbalanced by increased efficiency.

The following pioneer equipment was therefore recommended, viz., 3 *spades*, 3 *picks, and* 3 *axes*, for each cavalry troop, no single portion of these tools was to weigh more than 3lbs., and no single tool more than 6lbs.

These tools were accordingly made at Roorkee, and issued to five regiments to be tried at the Delhi camp.

After a short trial the following reports were sent in:—

From Officer Commanding 10*th Hussars.*

10*th Hussars* — Carries them all easily (except the long handled shovel) attached to saddles; approves of all patterns except the short spade. Has not however had an opportunity of trying them practically. Makes several other suggestions.

From Officer Commanding 11*th Hussars.*

11*th Hussars* — Reports that they do not answer the purpose for which supplied, and are very awkward to carry. Has lost the small hatchet supplied.

From Officer Commanding 15*th Hussars.*

15*th Hussars* — The six tools carried easily by three farriers. Condemns the spade, shovel, and picks. Approves of the hatchets.

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* This was not approved by H.R.H. the Commander-in-Chief.

From Officer Commanding 10th Bengal Lancers.

10th Bengal Lancers.	Reports the tools easily carried on the saddles, except the shovel. Does not consider the tools adapted for natives to work with, and suggests the hoe, phowrah, and bill-hook. Makes other suggestions.

Officer Commanding 1st Regiment, Central India Horse.

1st Regt., Central India Horse.	Reports that he has carried the tools in cases, on the off side of the saddle. They are easily carried, except the shovel, which is difficult. Approves of the long pick, hatchets, and shovel. Condems the small spades and pick, with screwed handles, as useless. Suggests the phowrah, instead of the spade, for native troops. Reports that the edge of the axe breaks when cutting green wood, and that being of English steel, it cannot be repaired. Suggests native metal for hatchets, as being easily sharpened and repaired.

Owing to the varying nature of these reports, the tools were tried practically before the Commander-in-Chief in India, by parties of the 11th and 15th Hussars, and 10th Bengal Lancers, the result of the trial being, the condemnation of the shovel, long pick, and long handled axe, and the approval of the small spade, short pick, and hatchet.

Shortly after this (in Sept., 1876) it was decided by the Government of India, that a further trial should be made, before introducing the equipment throughout the Cavalry in India.

The Commander-in-Chief accordingly selected the following three regiments, the 15th Hussars, 10th Bengal Lancers, and 14th Bengal Cavalry, in which a further trial of the proposed cavalry equipment might be carried out.

As it was thought impracticable to carry out the course suggested in the Committee's report, it was considered sufficient to teach the men practically, as far as could be done, the subjects in clauses *a* and *b* on page 1. (Camp and Regimental duties.)

The issue of three picks, three shovels, and three axes, to each troop of the three regiments above named, was accordingly demanded and sanctioned.

The introduction of pioneers into the British cavalry, having been approved of by the Commander-in-Chief, four regiments were selected for the purpose of trying the new system.

One subaltern and one N.-C. Officer of each regiment were ordered to be detailed for instruction at the S.M.E., Chatham, where they should receive about eight days instruction in the duties mentioned in clause *a*, and about twelve days instruction in those mentioned in clause *b*; the total duration of the course to be about one month.

Cavalry Pioneers in the Austrian Army.—

Before 1866 many of the Austrian Cavalry regiments had pioneers, who rendered such good services during the war, that it was decided to organize them in all the cavalry regiments.

These pioneers, selected from the men of the regiment, were clothed, armed, and equipped, like their comrades, except that they carry one tool in a leather case. They also receive a simple training as pioneers, after they have first passed their first-class in riding drill.

General Edelsheim's aim in creating this organization was to render the cavalry independent of the other arms, when acting as an advanced guard, by enabling it to surmount obstacles, &c., and the experience of eight years, has justified his experiment.

The officers in charge of the pioneers receive a few months instruction with engineers, and the pioneers soon acquire their special technical instruction. During the war of 1866, we find the pioneers distinguished themselves in the following ways :—

In defending bridges, villages, &c.
Forming roads of approach.
Blocking roads.
Destroying bridges.
Forming works to facilitate the employment of Artillery, and opening up roads for the same.
Breaking down palisades.
Clearing woods, &c.

The cavalry pioneers have a double duty, viz. :—

1st. To render possible the passage of obstacles in as short a time as possible.

2nd. To assist in the rapid formation of camps and bivouacs.

These duties necessitate the use of the two following classes of pioneers, in each cavalry regiment, viz. :—

1st. The *section* called the *regimental pioneers* (highly trained) and

2nd. The *squadron pioneers*, of which there are five to each squadron (except the 6th, which has none), for camp or fatigue duties.

The pioneer section furnishes the advanced guard, and the squadron pioneers perform the necessary duties at halt or bivouac. The pioneers for the pioneer section are selected from men having one, two, or three years service. The work taught is as follows :—

1st. First principles, use of tools, &c.
2nd. Construction of roads, &c.
3rd. Crossing watercourses, with and
4th. Without bridges, &c.
5th. Destruction of railways, &c.
6th. Camp duties.
7th. Hasty fortifications.

A cavalry pioneer section consists of 40 men, and one officer.

The tools carried by the pioneers are only four in number, viz :—

Spade and case	weighing	4·96	lbs.
Pickaxe	,,	6·28	,,
Hatchet	,,	3·42	,,
Axe	,,	6.83	,,

and of these, each regiment carries 22 spades, and 11 of each of the other tools.

Each regiment also carries 11 valises, containing pincers, file, jointed saw, claw hammer, pack thread, 75 nails and 2 spikes.

In war time each pioneer section carries 40 cartridges, each one containing 2 lbs. (Austrian) of dynamite.

The cartridges consist of a steel cylinder with oval base, filled with 2 lbs., (Austrian)* dynamite in the oily state.

The primer used is a cylindrical box fixed in one end of the steel cartridge, and containing a small quantity of dynamite ; it is fired by a cap into which the end of a Bickford's fuze is inserted.

The objection to the extra weight placed on the horses has not proved insurmountable in the Austrian Cavalry, which has smaller, and more lightly built, horses than the British Cavalry.

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* A pound or pfund Austrian equals 1·234 English lbs.

Destruction of Railways and Telegraphs by Prussian Cavalry.—

The Prussians have provided their troops with the necessary equipment and instruction, in destroying railways and telegraphs.

The pioneers are instructed in all the details of the permanent way, as well as with the construction and destruction of telegraphs. The tools carried by the cavalry pioneers are the key, auger, petard, grappling tackle, and cavalry hatchet.

Each squadron carries these tools, when on the march, in squadron carriages, and when on an expedition, on the horses. One N.-C. Officer and six troopers can dismantle a portion of a railway in ten minutes.

The following are some of the Prussian instructions on the subject, viz. :—

1st. No line to be cut without an officer's order.

2nd. Cavalry should always try to destroy lines in rear of the enemy.

3rd. All lines between the two armies to be respected in offensive movements.

4th. In retreat the Commander-in-Chief details the lines to be preserved, and those to be dismantled or completely destroyed.

5th. No work of art to be destroyed without special orders from the Commander-in-Chief.

M. T. SALE, CAPTAIN, R.E.,

Secretary R.E. Committee.

PAPER XIII.

EXTRACTS FROM PROCEEDINGS

OF

INDIAN PONTOON COMMITTEE.

Communicated by the Secretary, Royal Engineer Committee.

PROCEEDINGS of a Committee assembled at the Army Head Quarters, Camp Delhi, on the 18th January, 1876, in accordance with G.O. No. 100, of the 10th January, 1876, by the Right Honorable the Commander-in-Chief, to report on the description of Pontoon and Trestle Equipment best suited for India.

The Committee assembled pursuant to orders, and proceeded to consider the subject upon which they were ordered to report.

2. The Secretary informed the Committee that portions of the following equipments were in charge of the Corps of Bengal Sappers and Miners.

1.—Pasley's old pattern equipment.

2.—Pasley's new pattern equipment.

3.—Blanchard's infantry equipment.

4.—A light equipment designed for service in Abyssinia.

5.—The Austrian (Birago) equipment.

6.—An equipment lately made at Roorkee on the basis of that recently adopted at home, and consisting of both pontoons and trestles.

7.—A light equipment for mule transport. Of these Nos. 2, 6, and 7, were reported to be in camp at Delhi, and the remainder at Roorkee.

Note.—For brevity's sake these various equipments will be designated in this report by the numbers attached to them above.

3. The Committee were also informed that in England No. 1

was tried about 25 or 30 years ago in competition with Blanchard's heavy equipment, and that the latter was finally adopted for home service after an exhaustive series of experiments, and continued in the service until the year 1871, when it was replaced by an equipment determined upon report by the Standing R.E. Committee at Chatham, which had spent several years and much labour in the investigations and experiments connected with the subject. This last equipment is now the service one in England, and is understood to be considered very satisfactory.

4. In India No. 1 equipment was adopted 30 years ago, and being found deficient in floatation, and some other points, was modified, it is believed by Sir C. Pasley himself, into No. 2, which is now the service pontoon equipment in this part of the country.

5. The government having come to the conclusion that this equipment was not satisfactory, and that it might be improved upon, appointed a Committee in 1864, of which Lieut.-Colonel (now Major-General) A. Taylor, C.B., R.E., was President, to report upon the matter. No action was, however, taken on the report of this Committee.

6. In 1866 a quantity of Austrian equipment was made up and tried at Roorkee, but was not adopted into the service. More recently government sanctioned the construction of No. 6 equipment as an experiment, and this has been under trial more or less for two years. It is now in charge of one of the pontoon companies of the Sappers and Miners.

7. The lighter equipments have been constructed or received from England at various times, No. 7 having been only just completed, and not yet tried.

8. The Committee were of opinion that the reports of the proceedings of the R.E. Committee at Chatham, and of General Taylor's Committee of 1864, should be laid before them for their guidance; being satisfied that the best way of solving the questions entrusted to them within the time available for their consideration, is to adapt the home equipment as far as possible, to such special local conditions as may interfere with its adoption pure and simple, in this country. The Committee decided that their immediate object should be to test and compare the various equipments actually available under all possible conditions.

9. The Committee proceeded to the Sappers' and Miners' Park, where they inspected Nos. 2 and 6 equipments which they found there, noting several points for future trial and discussion.

10. The Committee assembled on the 20th January, 1876, at the Sappers' and Miners' Park (present the same members as before), and marched portions of No. 2 and No. 6 equipments across country to a point on the Jumna, which had been selected for bridging operations. In moving across country they observed a difference between the two equipments as regards mobility, which was in favour of No. 6.

* * * * * *

25. The Committee having made a number of experiments to ascertain the buoyancy of No. 6 equipment, were of opinion that these results were not sufficiently decisive to warrant the adoption of definite conclusions, but that the following points appeared to have been established :—

1.—That the flotation of the two descriptions of pontoons tried was insufficient.

2.—That the general arrangement of No. 6 equipment appeared to afford a basis for future experiment, but that further investigation, particularly into the question of transport, is required.

3.—The Committee were of opinion that bullock draught is entirely unsuitable to the requirements of a pontoon train in India in the present day.

4.—The Committee after perusing a copy of the proceedings of General Taylor's Committee (produced by Captain Blood from his office records), expressed no opinion as to the necessity, or otherwise, of pontoons being decked in; they wished first to consider the report of the proceedings of the R.E. Committee at Chatham, who recommended the partially decked pontoon now in the service at home, and to experiment further on the point.

* * * * * *

29. A bridge was formed over the Jheel Drain on the 26th January, 1876, with No. 2 equipment, the work taking 58 minutes. A detachment of Sappers, in fours, was marched on to the bridge, and there halted, and closed up. The Committee observed the heading up of the water at the stems of the pontoons, with a view to comparing it with the result of a similar experiment to be tried with No. 6 equipment.

30. Another bridge was then formed in exactly the same place with No. 6 equipment, the work taking 15 minutes. A crowd of men, as before, was placed on the bridge also, and the heading up

noted; no very obvious difference between the amount of heading up of water was, however, apparent in the two cases; the current, which was considered to be about $3\frac{1}{2}$ miles per hour not being sufficient to produce this effect in any very marked degree. The want of more flotation in No. 6 equipment was again apparent, the pontoons being immersed almost level with their decks.

31. The chief value of the experiment was that it showed what a difference existed in the rates at which bridges could be formed with the two equipments under circumstances as nearly as possible alike. The bridges were 60 feet long, and were formed at the rates given below:—

No. 2, 10·34 feet, in 10 minutes.
No. 6, 40 feet, in 10 minutes.

* * * * * *

33. It having been found (*ante* para. 25), that the flotation of No. 6 equipment was insufficient, it was decided to have a portion of that equipment arranged with pontoons at reduced intervals; and also to try whether, with such reduced intervals, a whole bay could be carried on a single carriage. Accordingly orders were given to reduce the intervals of 16 bays from 15 feet to 12 feet, to send the bridge thus arranged for trial to Hurdwar, and to prepare a carriage for a whole bay thereof.

34. The Committee then proceeded to try experiments in ferrying men in the pontoons of No. 6 equipment across the Ganges Canal at Roorkee. It was found that 15 unarmed natives besides a crew of four (two oars, one steersman, one bowman), could with ease and rapidity be ferried across the Canal, which was running about three miles per hour at the time.

35. It was decided to repeat this experiment the following morning with armed British soldiers, and to ascertain whether they could use their arms conveniently in the pontoons if required.

36. The Committee were fully impressed with the absolute necessity of providing some arrangement for ferrying troops across a river before or during the formation of a bridge, and they considered that the pontoons under trial met this requirement in a very satisfactory way; but they were of opinion that if these pontoons could be provided with some arrangement for closing them when required, their safety in bridge would be much increased thereby. Orders were accordingly given to have one pontoon fitted with light hatches for trial.

* * * * * *

45. On the 21st of February, 1876, a bridge was formed over a branch of the Ganges, at Hurdway, consisting of fourteen pontoons and one trestle, the anchorage being arranged by means of a wire rope passed across the river partly in and partly out of the water —about one-third of its length being under water.

46. A gun carriage made up to the weight of a 12-pounder Armstrong, without limber, was drawn over the bridge by hand. It was observed that the bridge would have carried a greater weight than this, probably to the extent of carrying a 16-pounder, M.L.R. under the same conditions.

57. Forty men were placed on two bays of the bridge, and it was considered that the intermediate pontoon was immersed as deeply as was considered safe; a wave raised by the force of the current (afterwards ascertained to be upwards of six miles per hour), washed occasionally over the decks of the pontoons. With the temporary hatch proposed by the Committee (*ante* para. 36), probably a greater load would have been admissible.

48. The same two bays were afterwards loaded with chesses until the centre pontoon was immersed to about the same extent as in the experiment with the men; the load on this pontoon was found to be 3285 lbs.

49. The Committee assembled, present the same members as on the last day, and proceeded to discuss the results of the experiments with a view to settling certain points as data for calculations.

50. The following points were agreed to:—

a As regards the maximum weight to be placed on the carriages of the equipment, the Committee found that the wagons of No. 6 equipment, weighing complete under 33 cwt., were not moved over deep sand and rough country without some difficulty with the existing transport, commissariat bullocks. They considered that these conditions were likely to occur on service, and should be provided for. Hence they arrived at the conclusion that the weight of pontoon carriages for Indian service should never exceed 35 cwt., as a maximum, and accordingly laid that down as a limit; making no exception on account of horses, since the object of providing horses instead of bullocks would be to secure greater speed, which would entail carrying the men in the pontoon wagons, and so increasing their loads probably to the extent of about 5 cwt. each.

For a two-wheeled cart carrying any part of the bridge

equipment it was laid down that 20 cwt., should be the maximum weight.

b A width of roadway of 9 feet clear having been approved by high authority for home service, the Committee decided upon that dimension as a minimum.

c The chesses forming the roadway should be $1\frac{3}{4}$ inches thick as a minimum, for the best teak wood.

d The maximum length of a single piece of a pontoon was assumed at 21 ft. 7 ins. (the length adopted for home service), as a basis for calculation.

e The greatest number of men that can be made available to work this length has been found to be 16; and consequently the weight of a single pontoon piece should not exceed 1000 lbs., or about 63 lbs. per man. Clarkson's material should be tried in this country, although the Committee felt very doubtful of its success in the Indian climate.

f Pending the trial of Clarkson's material for the covering of the pontoons, the choice appeared to be between copper and sheet iron, both of which have been tried in this Presidency. The opinion of the Committee was decidedly in favor of copper.

50. After the discussion, which led to the results detailed above, the Committee proceeded to the bank of the Ganges, where a bridge was formed at the same place as before with thirteen pontoons and two bay trestles, one on each bank.

51. A column of fours of unarmed natives, which covered all the floating portion of the bridge, was marched across in quick and double time. No sway whatever was perceptible in the bridge.

52. A raft was afterwards formed with two pontoons and moved across the stream by means of ropes worked from the bridge. No difficulty whatever was experienced in moving this raft about with a 12-pounder gun (without limber) upon it, and it was considered that with a raft of three pontoons instead of two, and suitable arrangements as to ropes, no difficulty should be experienced in moving a 40-pounder Armstrong over the river in the same way.

53. It was thought unsafe to attempt to row a raft in the rapid current for fear of its being carried away against the canal bridge below.

54. A pontoon was dismounted from a wagon and launched, and a crew of two rowers, one steersman, and a bowman, together with fifteen unarmed Sepoys as passengers, were placed on board in one

minute. The pontoon was afterwards rowed across the stream, sixty-four yards wide, with a maximum current of 6·2 miles an hour, and the men disembarked, all in 2 minutes 11 seconds, or in 3 minutes 11 seconds from the commencement of the unloading of the pontoon.

55. During these operations the rate of the current just below the bridge was determined, and was found to be 6·2 miles per hour, in one portion of the stream.

56. The formation of the bridge (68 yards long) took 45 minutes on these occasions; not including the placing of the wire rope to which the cables were secured. This operation took four hours, and was rendered necessary, as anchors could not be used owing to the great velocity of the stream and unfavourable nature of the bottom.

57. The Committee were much impressed with the great handiness and utility of the pontoons when used separately as boats in conveying ropes across the stream, and in other work connected with placing the wire cable alluded to above. This operation would have been much more difficult with pontoons which could only be used in rafts; unless, of course, special boats were carried with them as part of the equipment.

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68. The Committee assembled on the 2nd March, 1876.

69. They found on inspecting tables which had been prepared for them, that it was impossible to carry a complete bay of No. 6 equipment on a single wagon, even at 12-feet intervals, within the limit of weight laid down; and they accordingly decided that the 12-feet interval should be rejected, as it was open to many objections, and that no interval less than 15 feet should be recommended.

70. The Committee then proceeded to lay down the conditions which they considered should govern the design of a pontoon equipment for Indian Service, in continuation of the proceedings of the 22nd February, 1876. The following points were agreed to after prolonged discussion :—

a. The duty of a bridge train in India is two-fold. In the first place it should supply the wants of an army advancing rapidly in any country in which it might operate; taking ordinary conditions as to size of rivers, rapidity of currents, and weight of passing loads; and secondly it should be capable of furnishing a bridge of very high power for rivers of great width and rapidity, and for very heavy loads. These classes of duties may be entitled

those of the " Advance " and " Heavy " bridges respectively.

b. The conditions of safety for these bridges should be as follows :—

Advance Bridge.

With infantry, in fours, crowded at a check (560 lbs. per foot run of roadway) there should be a margin of one foot from the water to the lowest point at which it could enter the pontoon. With the 16-pounder M.L.R the same.

With a crowd at the rate of 84 lbs. to the superficial foot of roadway, there should be a margin of 6 inches from the water to the nearest point at which it could enter the pontoon.

Heavy Bridge.

With a load at the rate of 100 lbs. per superficial foot of roadway there should be a margin of one foot from the water to the lowest point at which it could enter the pontoon. The same with siege artillery. With the maximum possible load of (say) 133 lbs. per superficial foot of roadway, a margin as above of 6 inches.

71. The Committee considered that it would often be advantageous to provide a double roadway with the heavy form of bridge, when only light traffic was expected; and that arrangement should be made with this object.

73. Calculations were inspected which showed that a pontoon within the dimensions of the English one, but modified in form, would fulfil all the conditions laid down.

74. It was resolved that these calculations should be carefully checked, and that tables should be prepared showing the distribution of the stores, as per approved list, on carriages weighing not more than 35 cwt. each, when loaded complete; which, supposing the calculations correct, would give three carriages to two complete bays of pontoon or trestle equipment, at 15 ft. intervals.

75. It was decided that ribands, with halved ends, like those of the home equipment, should be tried; and that the length of chess for a 9-feet roadway should be left an open question pending the trial of these ribands.

76. The Committee did not approve of the English pattern of baulk with halved ends; since such baulks were not in their opinion

so useful as the ordinary pattern with full ends for making bridges with country boats and casual materials; a very important point for Indian service.

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82. The Committee having resumed their consideration of the bridge train on the 3rd March, 1876, calculations were submitted by the Secretary, showing that a pontoon of the following dimensions would fulfil all the conditions of the "Advance Bridge":—

Length at top	...	21	feet	7	inches.
Width Amidships { On deck ...	...	5	„	3	„
{ At bottom ...	...	4	„	6	„
Width on deck at bow ...	...	4	„	6	„
Width at square stern { On deck ...	...	5	„	3	„
{ At bottom	...	4	„	6	„
Depth { From deck ...	...	2	„	$4\frac{1}{2}$	„
{ From top of coaming ...		2	„	$3\frac{1}{2}$	„
Depth at bow	...	2	„	$8\frac{1}{2}$	„

The bow to be shaped as in the present Roorkee equipment (No. 6), and the general construction to be the same as in that equipment, but the stern to be square, with a view to enabling a heavy bridge to be formed by doubling the pontoon pieces of the advance bridge.

83. As the calculations were found to be correct, and as they showed that the pontoon proposed met all the requirements laid down by the Committee, the above arrangement was approved.

84. With reference to Trestle Equipment, the Committee approved generally of that which they found in use at Roorkee, and which they were informed had been extensively tried during upwards of 4 years. They had, however, no opportunity of comparing this trestle practically with any other.

85. Tables showing the scale and distribution of bridge stores were approved, as was also a scale of miscellaneous tools and stores for a unit of bridge train.

86. With reference to transport, the majority of the members of the existing Committee did not think it necessary to the efficiency of the bridge train that the whole of it should be horsed, as recommended in the proceedings of the 22nd January, 1876, and they accordingly felt at liberty to propose a scale of transport consisting partly of bullocks, which was ordered to be included in their report. At the same time the Committee wished to record a very strong opinion that it is absolutely necessary to provide bullocks of the

best quality for the bridge train, and to attach them permanently to the Corps of Sappers, as is done with heavy batteries; the drivers and others being placed on the same footing as to pay as in the Artillery.

87. A scale of transport was also approved for the various telegraph equipments and was ordered to be included in the report of the Committee.

88. The Committee then adjourned, and the members then separated to their various stations.*

* * * * * *

6th March, 1877.

89 The Committee having been reconstituted assembled pursuant to order, read over and considered the proceedings of last year, and the papers connected with the subjects on which they were ordered to report.

90. The secretary explained that after General Stewart's Committee separated, arrangements were made for the construction of 4 pontoons with superstructure, and 2 waggons on the pattern approved by them, and that these stores were complete and ready for trial. He also stated that as it was felt to be desirable that these pontoons should be actually tried before being recommended to Government, no formal report had yet been submitted.

91. The Committee then proceeded to a tank, where 3 pontoons of the pattern proposed by last year's Committee were formed into bridge singly in the "advance" form, and a load of sand-bags was placed on the bridge to test the flotation and the strength of the pontoons. When a load of 7,400 lbs. each had been placed on a pair of pontoons, a diagonal strut in one of them gave way, and the pontoon was removed for repair.

92. Orders were given that all the corresponding struts should be strengthened in the 4 pontoons with a view to further trial, and to determine their proper dimensions. These dimensions, as well as those of all other parts of the pontoons, had been reduced as far as seemed possible, with a view to lightness.

93. A gun carriage made up the weight of the 16-pounder M.L.R. was then run across the bridge several times and the effect was noted.

94. It was observed that the amount of flotation provided was ample for this load, as when the pontoons were floating upright

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* The Committee was dissolved after March, 1876, and reconstituted in March, 1877; only two members of the former Committee being on the second or reconstituted Committtee.

they were only immersed to within 14 inches of the tops of their coamings, giving 2 inches more height than is required by the conditions laid down by General Stewart's Committee (Proceedings, para. 70).

95. It was found, however, that the pontoons when loaded with both the above weights were laterally unstable, and tipped over until the edges of their coamings came in contact with the lower part of the roadway. This point was carefully examined, the gun carriage being repeatedly run over the bridge and halted on it, and the Committee agreed that it formed a fatal objection to the use of the pontoons as they stood, especially in rapid currents. Arrangements were made for placing stops at the sides of the pontoons, to come in contact with the roadway and check the tipping tendency, and to try this on the following day.

96. The Committee then inspected the 2 waggons which had been prepared, and observed that owing to a change which had been made in the way of carrying the pontoon, 4 inches could be added to its width at top and bottom, which would give additional flotation, and thus enable the pontoon to be reduced in height, which would increase its steadiness in the water. They also agreed that 5 inches might be added to the length, making it 22 ft. instead of 21 ft. 7 in., and that the extra length should be utilized in giving a more sloping bow.

97. The Committee again saw the carriage loaded up to the weight of the 16-pounder M. L. R. run over the bridge as altered according to yesterday's orders, and crowded men were also marched over it; but they were not satisfied with the working of the stops, which they considered inefficient and likely to interfere with the formation of the bridge in some localities; especially where there happened to be a rise from the bank to the first pontoon; and they agreed that the instability of the pontoons must be overcome in some more satisfactory way.

98. In order to investigate the subject thoroughly they ordered one of the experimental pontoons to have its central road-supporting beam lowered $3\frac{1}{2}$ inches, and two of No. 6 pontoons to have their beams raised, one to correspond with the experimental pontoons as originally tried, and one with that now ordered to be altered. The objects of this experiment were:—

A. To find what effect was produced by the square sterns of the new pontoons as compared with the similar ends of the No. 6 pontoons.

B. To note the effect of lowering the points of support of the roadway.

99. The Committee were satisfied with the alterations made to the frames, and found that the new struts which were fitted in the room of the original ones, some of which had failed, were sufficiently strong. They afterwards inspected the new pattern trestle equipment.

100. On the 14th March three pontoons were put into bridge as follows:—

1.—A pontoon of No. 6 equipment with both ends rounded, and with its saddle raised to the same height as those of the new pontoons.

2.—Another of the same pattern with its saddle $3\frac{1}{2}$ inches lower.

3.—A new pontoon with its saddle lowered $3\frac{1}{2}$ inches.

101. Owing to the bad weather these pontoons could not be tried very fully, but enough was done on this and the next day to lead the Committee to the conclusion that if the new pontoon were to be lowered four or five inches, and widened as much as possible at the same time, it would be sufficiently stable.

102. The flotation of the new pontoons was carefully tested by loading them with sand-bags and Sepoys weighed just before being put on to the bridge. It was found that the new pontoon did not give the expected margin of safety with the weight of crowded infantry in fours by about $1\frac{1}{2}$ inch, which was attributed partly to error in calculating the area of the curved part, partly to excess of weight in the pontoon over what was expected, and partly to the thorough soaking it and the superstructure had received in the late rain.

103. Two pontoons were coupled together into the "heavy' form and placed in bridge for trial. As a preliminary to test the flotation, a load of Sepoys was placed on the bridge, and from this it was seen that the flotation of the heavy form was in excess of actual requirements as laid down. It was resolved to go further into this matter on the next day of meeting.

104. A bridge was afterwards formed across the canal with No. 6 equipment, consisting of 14 pontoons with two trestles at one end. Carriages weighted up to the 9-pounder and 16-pounder standards were passed over the bridge and the effect noted.

105. The Committee made a careful inspection of the advance and semi-permanent telegraph equipments, which were worked in their presence. The advance equipment is carried on wheeled

vehicles; and the semi-permanent equipments on elephants and other transport animals and vehicles as may be convenient. Scales of stores and transport were approved and ordered to be included in the report.

106. In the evening a pair of new pontoons were coupled into a pier for the heavy form of bridge, and were placed in a tank for experiments, being formed into bridge with double baulks and chesses, as proposed for service. A gun carriage loaded up to the weight of the 40-pounder B.L.R. was run on to the bridge, and with this load the margin of safety was observed to be $17\frac{1}{4}$ inches near the junction of the two pontoons forming a pier of the bridge. This margin was about $1\frac{1}{2}$-inch greater at the ends of these pontoons, which rose slightly owing to a little play being left in the couplings.

107. Afterwards, a load of men crowded together was placed on the bridge, with a view to testing the strength of the arrangement generally; and an alteration was ordered to be made in the mode of fixing the central saddle. The load carried was 9,240 lbs. on the single pier. The margin of safety was $16\frac{1}{2}$ inches near the junction with this load.

108. The pair of pontoons coupled into a pier of the heavy bridge having been again placed in the tank, with a doubled roadway as before, and the alteration ordered having been also made, a load of 11,230 lbs. was placed on the pier, which gave a margin of safety of $14\frac{1}{2}$ inches near the junction and 16 inches at the ends. After this trial, two diagonal struts were observed to be split at the end where they abutted on the angular corner piece at the bottom of the pontoon, the split being due to their shape at that point and showing that the mode of fixing requires alteration. The Committee thought that with this alteration the arrangement promised to be successful. It should, however, be further tried with several piers, in a current, before being finally adopted. The Committee decided to adjourn to Hurdwar to observe the bridging operations there in connection with the Hurdwar Fair.

109. The Committee then proceeded to Hurdwar in order to enable the new members to observe the mode of constructing bridges in a rapid current with No. 6 equipment, which is in charge of the 10th Company, Bengal Sappers and Miners, and closely resembles the pattern proposed for adoption by the Committee; and also with the trestle equipment approved.

110. In one of the bridges constructed at Hurdwar in a very

rapid stream, two piers of doubled pontoons were placed, and carried all the heavy traffic of the Fair there for a fortnight.

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The Committee then prepared, and on the 29th March, 1877, submitted the following report :—

REPORT.

1. An army operating in a country intersected by rivers, will usually require bridges of two kinds to be made for it; namely, those to enable the advancing columns to overcome obstacles as they meet them, and those of a more permanent description intended to complete the lines of communication in the rear, after the main body has passed on.

2. The first, or "advance" class of bridge, must be sufficiently portable to accompany and even sometimes overtake the advance of the army, and to move over any ground and to any point accessible by the three arms; while at the same time it must be so arranged as to be "formed" for use as quickly as possible, and to give as high a degree of safety as may be consistent with other requirements.

3. The "heavy" class does not as a rule require to be so portable, but must give much higher standards of safety, and must be capable of bearing such heavy and continuous traffic as is entailed by the passage of siege trains.

4. It is, of course, a great advantage if the requirements of both these classes of bridge can be met by the stores of the same equipment, and it is believed that the only satisfactory attempt in this direction has been made in England, where a heavy bridge is formed from the advance one merely by strengthening the roadway, the pontoons being considered to afford enough flotation for either form; but the Committee think that this arrangement is not sufficiently powerful to meet the requirements of service in this country. They observe that the English pontoons in "heavy" bridge are open, and are depressed to within 6 inches of their coamings by siege artillery, and it seems certain that under such circumstances they would be swamped in the Indus at Attok, or in the Ganges at or near Hurdwar even in cold weather, while it is also certain that bridges might frequently have to be made in India under at least as unfavourable conditions as those presented by the two localities named, so that pontoons of much higher power for heavy bridge purposes than those of the home equipment, must be provided for India.

5. Another objection to the English system is, that its loaded carriages are much too heavy for advance work. It seems clear that if a pontoon train is to keep up with the advance of all arms, its carriages must not be greatly heavier than those of the lighter Field Artillery, and the Committee have accordingly agreed upon a maximum limit for the loads they recommend of 35 cwt.; being about the weight of a Field Artillery gun, the weight being calculated without that of men carried in each case. Now the weight of the English pontoon carriage complete, is about 39 cwt., and would be more if it were made up of stores of Indian materials. This is too high for service in India, and indeed, there seems to be a strong feeling at home that it is so for European service also (see the *Soldier's Pocket Book*, p. 306).

6. For these reasons the Committee do not recommend the adoption of the English pontoon system in its entirety for Indian service; but at the same time, as it comes nearer to what is wanted than any other with which they are acquainted, and as the objections above mentioned can be got over without (in their opinion) sacrificing any other material points, they have taken it as the basis of the system which they recommend, and they now proceed to describe the alterations which they think necessary to fit it for Indian service.

7. In the first place, it is intended to adhere to the plan of constructing the heavy bridge with the stores of the advance one, but to do this by coupling the advance pontoons in pairs, end to end, to form piers for the heavy bridge, as well as by strengthening the roadway, and thus to obtain a bridge of ample strength and flotation for any traffic likely to come on it. The pontoons should further be fitted with covers, removed when the former are required for use in ferrying, and should have one end of each made square to facilitate their being coupled together.

8. As regards the dimensions of the pontoons proposed, it has been found that the limits of width and length have been reached, and that if the height goes beyond a certain point the pontoons become unstable, and thus safety though apparently gained is sacrificed. As it is also considered that some reduction on the English standards of flotation is admissable, on account of the proposed closing of the pontoons, and the better arrangement for a heavy bridge, the Committee (taking the limits of length and width referred to) have fixed the height of their pontoon so that it will not be actually immersed by the greatest load when in advance bridge

(disorganized infantry crowded), while it will be sufficiently stable, and will afford ample flotation for ordinary loads in advance formation, and will give the standards of safety in heavy bridge which were laid down by last year's Committee. The dimensions proposed will be found in the description attached, together with the lines of flotation under different loads. The Committee recommend that a few pontoons of this description should be made and thoroughly tested, and that if they afford the flotation and stability expected, they should be adopted into the service.

9. The remainder of the bridge stores of the pontoon equipment need not differ in any important point from those of English patterns. A descriptive list will be found attached, with reasons for the departure from English patterns where any such are recommended.

10. With reference to the trestle equipment, the Committee recommend the adoption of the pattern in use at Roorkee. The same superstructure and carriages are used indifferently with this equipment and with the pontoons, and although in its ordinary form it will only carry the ordinary loads provided for by the advance bridge, it can be adapted for heavy traffic without difficulty.

11. The last important point in which it is proposed to modify the English system, is the arrangement of the equipment for transport. It has been mentioned that the carriages of the English equipment are too heavily laden for Indian service, and the Committee have laid down a maximum weight of 35 cwt. (without men) as the limit of a bridge train wagon complete. In accordance with this proposal, they recommend that three carriages should be allowed to every pair of pontoons with their stores, instead of one carriage per pontoon and stores, as in the home equipment. This arrangement will entail 36 bridge carriages for a train of 120 yards of bridge, but in those carriages almost all the accessory stores and materials will also be conveyed. The English equipment of the same length has only 25 bridge carriages, but as accessory stores are carried in extra wagons, a total of 31 is required. Thus, the increase proposed is not great, while the advantage of having lighter loads is important.

12. With reference to the amount of bridge train which should form one unit of equipment, the Committee would recommend the adoption of the British standard of 120 yards of bridge in the absence of any apparent reason against it. They would, however, suggest a departure from the home proportion of pontoon to trestle equipment,

and would propose 80 yards of the former to 40 of the latter to each unit, instead of 100 yards and 20 yards respectively, since they consider 20 yards of trestles too small a quantity of that class of bridge to be of much use. Such a unit should be the regular equipment of each of the pontoon companies of Sappers and Miners, and should be kept as complete as possible in transport, and all requisites for service. Thus, at Roorkee were there are two pontoon companies of Sappers, two complete units should be kept up, both of which should be provided with bullocks of the best quality permanently attached to the companies, as is done with heavy batteries, the drivers and others being placed on the same footing as to pay, &c., as in the Artillery.

General Description (Dated 20th April, 1877,) of Bridge Equipment Proposed.

1. The bridge is formed of "pontoons" or "trestles," kept at 15 feet central intervals by baulks, resting on transoms in the case of trestles, and on saddles laid on central saddle-beams in the pontoons.

2. In the "advance bridge" the pontoons and trestles are used singly; while in the "heavy bridge" the pontoons are coupled end to end in pairs, and the trestles are doubled in order to form supporting piers of sufficient power for siege artillery, &c.

3. The number of baulks used is five for the "advance bridge" and nine for the "heavy bridge;" they support chesses, which are kept in position by a riband on each side, racked down by rack lashings to the outer baulks, and leaving a clear roadway of 9 feet in the narrowest part. In cases where very heavy continuous traffic is expected, the chesses of the heavy bridge are doubled. In all cases the chesses are prevented from slipping laterally by chess pins, and a slight handrail is arranged by stretching a rope along each side of the bridge supported by oars placed in sockets in the pontoons.

4. The bridge is usually secured by means of anchors of the Trotman pattern, and cables of 3-inch rope.

5. The equipment is carried on 4-wheeled wagons, of which three are required for every two bays of the bridge; a bay being a pontoon or trestle with all the stores required to cover the interval between it and the next pontoon or trestle in bridge. These wagons are all exactly alike, although, of course, their loads differ, and when packed complete they do not exceed a maximum weight of 35 cwt. They are intended to be drawn by 6 horses or bullocks.

6. The buoyancy of the pontoons in "advanced bridge" has been calculated so that they shall be safe from submersion under an extreme load of 84lbs. per superficial foot of clear roadway, or disorganised infantry crowded together at the rate of about 55 men to 100 superficial feet. With this load the pontoon is immersed to within an inch of its deck, or three inches of its covered hatchway; while with the 16-pounder M.L.R. equipment fully horsed it has about one-quarter of its total flotation to spare (or nine inches of height from water to covered hatchway); and with infantry in fours crowded at a check (560 lbs. per foot run of bridge) it has about $7\frac{1}{2}$ inches margin from water to hatchway.

7. When two pontoons are coupled end to end in heavy bridge with a strengthened roadway they give a margin of safety, under the 64-pounder M.R.L. with limber, of about 14 inches; and under a load of 100 lbs. per superficial foot of roadway, of about $11\frac{1}{2}$ inches; while even under the extreme load of 133 lbs. per superficial foot of roadway they give a margin of $7\frac{1}{2}$ inches.

8. The pontoon is a boat with decked ends and partly decked sides, where six rowlock blocks are fixed. The undecked portion of the pontoon is $15' \times 4'\ 7''$, and is surrounded by coamings 2 inches high, over which covers are placed, with canvas flaps buttoned to brass studs on the sides of the coamings. The principal dimensions of the pontoon are as follows:—

Length on deck		22 feet.
Width	on deck	5 feet 7 inches.
	amidships	
	at bottom	4 feet 10 inches.
Depth	from deck	2 feet 2 inches.
	from top of coaming	2 feet 4 inches.

The pontoon differs from the English pattern in having one end square, and in being somewhat longer, wider, and shallower; the square end being given with a view to facilitating the coupling of the pontoons in pairs to form heavy bridge. The pontoon consists of six sets of framed ribs, connected by a kelson and side and bottom streaks, and covered with copper sheeting. There is a cleat at one end to secure the cable; the bottom is provided with two plug holes to let the water out, and there are 18 handles outside by which it is carried by hand and secured to the wagon for transport. There are three thwarts which support the saddle beam. The pontoons are coupled together for heavy bridge by means of iron tie-rods secured to the saddle-beams. The saddle-beams are thus thrown into com-

pression, and the thrust is taken by a moveable beam placed centrally over the junction of the pontoons; the whole system becoming a double truss, and throwing the weight vertically on the pontoons, which are thus protected from undue strain.

9. A trestle consists of the transom, two standards, two keys, and two shoes, the same superstructure being used as with the pontoons. The transom is a teak beam, 17 feet by 9 inches by $6\frac{1}{2}$ inches, with strengthened mortices at the ends to admit the standards. The standards are of teak, of three lengths, to suit various heights; namely, 18 feet, 13 feet, and 8 feet, and they are all 9 inches by 3 inches thick. They are pointed, and shod with iron at the lower ends, and fit into shoes 2 feet 9 inches by 1 foot $2\frac{1}{2}$ inches by $3\frac{1}{2}$ inches. The keys are pieces of teak, 2 feet by $3\frac{1}{2}$ inches by 2 inches, which clamp the standards in the mortices of the transoms.

10. The saddle beam is a piece of teak, 11 feet 2 inches, by 6 inches, by 3 inches, with the top slightly rounded. It is permanently fixed in its place in the pontoon. The saddle is a framing of teak 11 feet 9 inches, by $6\frac{1}{4}$ inches, by 3 inches, which fits over the saddle beam, and has 5 sets of three-curved cleats to receive the ends of the baulks. There are handles at each end which also serve as cleats for cables and breast-lines.

11. The baulks are of teak, 15 feet 8 inches, by 6 inches, by $3\frac{1}{4}$ inches, provided at the ends with claws of $\frac{3}{8}$-inch flat iron to prevent their slipping off their saddles. The chesses are teak planks, 11 feet by 12 inches by $1\frac{3}{4}$ inches. The ribands are identical in every respect with the baulks. The chess-pins are $7\frac{1}{2}$ inches long, of $\frac{3}{8}$-inch round iron, with an eye at top. They are strung in sets of 15 on $\frac{1}{2}$-inch rope, and are inserted in $\frac{1}{2}$-inch holes in the chesses outside the ribands and baulks. The shore-transoms are beams of teak used for the shore ends of the bridge, and are 13 feet 6 inches long by $6\frac{1}{4}$ inches by 6 inches. They are secured to the ground by pickets 3 feet by $2\frac{3}{4}$ inches, passing through 3-inch vertical holes in the transoms.

12. There are several points of difference between the superstructure described above and that of the home bridge. The saddle-beams of the home equipment are hollow, while those proposed for India are solid, and are better suited to the climate. This reduces the width of the beams and saddles. The baulks of the home equipment are halved at the ends, while those proposed are not so, and are considered simpler and better both for special and general purposes. The chesses of the proposed equipment are 1 foot longer

than the home ones, giving the same clear roadway, and more overlap and play at the ends. Special ribands are used in the home equipment, but the introduction of chess-pins in the proposed equipment enables baulks to be used for this purpose, and so simplifies matters.

13.—A unit of bridge train comprises stores complete for 80 yards of pontoon and 40 yards of trestle bridge.

M. T. SALE, CAPTAIN, R.E.
Secretary, R.E. Committee.

PAPER XIV.

FORTRESS WARFARE.

By Lieut.-Colonel Schaw, R.E., *Professor of Fortification and Artillery, Staff College.*

A Lecture delivered in the Prince Consort's Library, at Aldershot, on the 6th December, 1875.

When, some little time ago, General Herbert asked me to give a lecture "about forts," I had a momentary misgiving when I pictured to myself the feelings with which a notice of a lecture on such a subject would be received by the majority of English officers. To the minds of most, the term "fortress warfare" naturally brings up a vision of Vauban's first system, and of those geometrical "*voyages en zigzag*," by which an enemy who did his *devoir* was always expected to approach a fortress—school exercises with which we are all painfully familiar. To some, indeed, it must have a more real, though hardly more agreeable signification, recalling the hardships and privations, the muddy trenches, and the "follow the Sapper" of twenty years ago, when we fought the Russians at Sebastopol, and learnt in our fortress warfare there how unprepared we were for war. But a little consideration reconciled me to the attempt, and led me to the belief that I should be able to put fortress warfare in such a light before you as to show that it is by no means altogether the Engineer's *spécialité*; and that, although it must always savour somewhat of slowness, yet it is far from being devoid of incidents calling for the display of enterprise, dash, and readiness of resource, as well as for those still higher qualities of good soldiers—patient courage, perfect discipline, and cheerful endurance of hardships; and, further than this, that fortresses exercise so great an influence on modern war, that no soldier can afford to neglect so important a branch of his profession as the study of fortress warfare.

It is true that fortresses had, apparently, little to do with the courses of the wars of 1859 and 1866, yet it is to be observed that peace was readily made by the conqueror in each case, when further success could only be obtained by the reduction of fortresses—the quadrilateral in 1859, the semi-permanent intrenched camp at Floridsdorf in 1866. And there can be no doubt that the existence of these fortresses materially altered the terms obtained by the Austrians.

Nevertheless, the nature and rapid courses of these two campaigns led to the opinion, very generally expressed at the time, that the genius of modern war was opposed to fortresses, and that in future the decision would always be arrived at rapidly in the open field. The events of 1870-71 have shown how unfounded was this opinion.

Metz was the centre towards which the forces of both sides gravitated in the first stage of the war, and when the battle of Gravelotte terminated unfortunately for the French, their permanent intrenched camp saved them from immediate disaster, and enabled a beaten army of 175,000 to keep at bay a victorious one 230,000 strong, for ten weeks. That Metz was imperfectly armed, insufficiently provided with food and shelter for the army that took refuge there, and that the man who, unfortunately for France, commanded this her only effective army, was, to say the least, incompetent to make use of the advantages of his situation, are all well known facts now. Had the conditions been more favourable to France, the influence of the great fortress of Metz on the general course of the war would, doubtless, have been very much more marked. But it is, probably, at Paris that we see the most important results obtained by a great fortress, for here 220,000 soldiers of the finest army in Europe, were stopped in their career of victory by one French corps, backed by an undisciplined mob, and obliged to maintain an investment with great difficulty, and often in a most critical situation, and enduring all the hardships of a winter campaign for more than eighteen weeks. At one time, indeed, it seemed as if all the power of the German arms, and the skill of the German generals would have been frustrated by this unexpected and prolonged resistance, affording time, as it did, for the development of the full military power of France. If the untimely fall of Metz had not set at liberty the army under Prince Frederick Charles, there can be little doubt that the Germans would have been constrained to desist from this attempt to reduce Paris, and would have had to fight for their own communications. I need not refer

further to the important part played by the smaller fortresses of France, than to observe that they were badly placed as regards the great railways leading from the frontier to Paris, and that not one was properly armed, garrisoned, or prepared to resist modern means of attack, and yet they occupied a large fraction of the German armies, and influenced materially the general plan of their operations. German writers agree in stating that if fortresses had existed at Chalons, Soissons, Rheims, and Troyes, the march on Paris, and the maintenance of its investment would have been so extremely difficult as to be practically impossible until, at least, one of them had been reduced.

A glance at the other side, as it existed during 1870-71, shows us the formidable fortresses on the Rhine holding the great crossings of the river, and making it imperative on France to capture one at least before her armies could march on Berlin; while now the two additional great intrenched camps at Metz and Strasbourg still further strengthen the German frontier. So firmly implanted in the German mind is a determination that the foreigner who once trampled on their rights and liberties shall never again obtain a footing in the Vaterland, that the energies of the nation have been for many years devoted to so strengthening the Rhine frontier that the invasion may be as difficult as possible, and this frontier defence has taken precedence of the defence of the capital, because the Rhine forms in itself so strong a natural barrier, and the capital is so far removed from it.

Without, however, attempting to sketch the defensive systems of continental nations, we must, before proceeding further with our subject, consider for a few minutes the objects with which fortresses are constructed, and, consequently, the end and aim of the special fighting which may occur in connection with them.

Fortresses may be divided into two general classes—fortified *places* and fortified *positions*—the former have for their object the security of particular places which are of value in the general defence of a country, such, for instance, as junctions of railways leading to the capital, mountain passes, important river crossings, which all have to do with the free movements of armies, hindering those of the enemy while facilitating the defenders; or magazines, depôts, arsenals, dockyards, or intrenched camps, which have to do with the supply of armies and navies, and with the maintenance and training of troops. Very generally, one and the same place fulfils several of these conditions, as, for instance, Portsmouth, which is a great naval

establishment, and, at the same time, an intrenched camp; and Metz, which is a depôt and magazine, a double bridge-head on the road between Paris and Berlin, and an intrenched camp.

The importance of a place may be so great for a particular theatre of war, or for a whole country, that possibly the result of the campaign, or even that of the whole war, may depend on its possession. In this case it must be so prepared by fortifications that a great part, or even the whole of the army, may be employed in its defence in addition to its own garrison. Of such a nature are the defences of Paris, of Antwerp, or the works designed for the defence of London-positions prepared for the home army to contend with the army the enemy is able to put into the field, and with which it is to be supposed the home army is not able to cope in unprepared positions. The struggle in this case is not for possession of the *place* so much as for the overthrow of the opposing *army*, and, therefore, it partakes more of the character of a fortified position than of a fortified place, although, in fact, the two must almost always, more or less, co-exist in a large fortress. It is necessary, however, to bear in mind clearly what is the object with which a fortress is constructed when either its attack or its defence is to be undertaken. When it is merely a *place* which is fortified, however necessary it may be that the place should be held or won, its fate will not decide the war, but is only one of the steps towards the decision, and it may be that a decisive battle elsewhere will entail its fall incidentally. When, however, the main army is to be dealt with in a fortified *position* it is the decisive struggle of the war, and the taking or holding of the place is a question of little importance compared with the result of the struggle between the opposing armies.

Thus, in the Crimea, the taking of Sebastopol would have had but little influence on the decision of the war had not the whole of the available forces of Russia been drawn into the struggle at that place, and it was, probably, a most fortunate mistake for us that we did not attempt to carry the place by storm when we first appeared before it. We have learnt after the event that most likely we should have succeeded; but to bring the war to a conclusion, we should then have been obliged to advance into the interior of the country, where our difficulties would have increased as those of the Russians diminished, and the result might have been very different from that which occurred, more by the exhaustion of Russian men and resources, by their long marches through dreary steppes to reach the theatre of war, than by the defeats we inflicted on them.

On the other hand, the fall of Belfort would not have had much influence on the general result of the war of 1870-71, while the fall of Paris and the defeat of Bourbaki's army entailed the fall of Belfort.

One more word on the general subject of fortresses appears necessary. If it be granted, as is undoubtedly the case, that armies must have secure depôts, magazines, and sources of supply, as well as hospitals, communications, and so forth, these must be guarded against hostile enterprises. The guards so employed are abstracted from the effective army in the field, and, if they are not aided by fortifications, they must be strong in numbers, discipline, and organization. But it is most important that a minimum of men, and these the least fitted for active service, may be able effectively to perform the duty, and this can only be obtained by the use of fortifications. Thus we come to the result that a well-considered system of fortresses, in which the number of points to be guarded is reduced to a minimum, so far from abstracting men from the field army, swells its numbers just in the proportion that fortifications enable us to diminish the strength of the guards otherwise necessary to secure the maintenance and supply of the army.

Having so far cleared our way by giving briefly the arguments from theory and from fact which justify the use of fortresses, and the general objects they are intended to fulfil, let us pass on to review the different phases of fortress warfare which may be developed in the course of a campaign.

For the assailant to invade the territory of the foe, it may be necessary to neutralise, in some way, the smaller or larger fortresses, which may bar his roads and interfere with the maintenance of his communications; he may have to meet and fight the enemy either in fortified positions or supported by fortresses, and, supposing the active army to be defeated, he may have to reduce all the strong points in the country which contain material of war, which cover beaten troops and allow them time to re-organise and rally, or which form a nucleus for the raising, training, and equipping of fresh armies, while his own fortresses secure his communications and sources of supply from a counterblow of the enemy, and, in case of failure, cover his retreat, and favour his re-organisation.

For the defender, fortresses gain time at the beginning of the war by delaying the progress of the enemy's march, they diminish the invader's active forces as he advances into the country, because he must leave troops behind to guard his communications against

sorties from the fortresses he has not taken; they lend all the aid that can be derived from the combinations of art to help the weaker army in the decisive struggle, and in the manœuvres which may precede it. Supposing the defender's active army to be defeated, it may be preserved from destruction by the refuge afforded by an intrenched camp, and holding there to watch it a superior force of the enemy, time is gained for further combinations, or an honourable peace may be hoped for should the assailant not be prepared for the prolonged and arduous efforts necessary to reduce the defender's fortresses. Should, however, the war be carried on "*à outrance*"—as was the war of 1870-71—it becomes henceforward almost entirely a war about fortresses.

What, then, are the different ways in which a fortress may be dealt with?

1. It may be masked; *i.e.*, a sufficient force may be left to watch a fortress which is so near the lines of communication of an army as to endanger it by sorties, but not near enough to bar the way by its fire.

This duty may be performed by a force little, if at all, superior to that of the garrison in infantry, but it must be superior in cavalry and field artillery.

The general plan would be somewhat as follows:—

The infantry, with their artillery, take up a position between the fortress and the line to be covered, closing all the direct roads to the latter. Their outposts push on to within about a mile of the fortress, and watch all its issues on their side. The cavalry take up the line of outposts on the far side, and the main body of the cavalry is so posted that any attempt on the part of the cavalry in the fortress to sally out, and by making a wide circuit to get at, and destroy or injure any part of the line of communications, may be met and frustrated by a superior force of cavalry. At night the chain of sentries and vedettes is closed in as near to the fortress as possible. The cavalry, although unable to resist any sortie from the far side of the fortress, yet give timely notice of its being made, and of the direction in which the troops are moving. Bitsch and Toul were both masked during part of the war of 1870-71, and, at the former place, many encounters between the garrison and the force left to watch them took place from time to time, in which neither side had a marked advantage. At Toul, only one Landwehr regiment was left for some days to mask the garrison, who, however, supposed they were in the

presence of a much larger force, and made no attempt to attack them, or to strike at the German line of communications.

The mere masking of a fortress, although it may prevent its garrison from sallying out to injure the communications of the other side, does not tend towards gaining possession of the place. Sorties for the purpose of foraging can be made with comparative impunity on the side which is only watched by cavalry, and relieving troops may also enter on this side, so that there is no probability of the garrison being starved out, nor is any pressure put upon them.

2. Should it be considered necessary to get possession of the fortress, one of the following methods must be resorted to:—bombardment by field artillery, surprise, storm, investment, bombardment by siege artillery, or regular siege. The first of these—bombardment by field artillery—ought not to succeed if the fortress is properly provided with bomb-proof accommodation, and if it does not enclose a large civil population. Even, in the latter case, if the Commandant be firm, and the place be tolerably large, the amount of injury inflicted by field artillery is so much less than might be expected, that no result ought to be obtained. A few fires will be started, which, with proper precautions, may generally be extinguished if energetically taken in hand at once, and there will be a certain proportion of casualties; but the experience of the late war goes to prove that the effect of field artillery is not so great as to produce an *immediate* result, and the supply of ammunition carried into the field is not sufficient to permit of the bombardment being continued so long as to produce that state of nervous horror which will demoralize the garrison and force a capitulation. If, however, the Commandant be incompetent, the troops inferior, and the civil population un-patriotic, such a course may succeed. As an example of a successful bombardment by field artillery, the case of Marsal, in 1871, may be cited. Marsal is a small fortress on the Seille, at the junction of the roads leading to Nancy from Strasbourg and Phalzburg. Seven field batteries, escorted by cavalry, were sent forward to reduce the place. The guns were placed on rising ground commanding the fortress, and it was summoned to surrender, but refused. Twenty-one rounds were then fired, when the white flag was hoisted. The garrison, however, was only a few hundred men, and there was no heart in the defence. Another example of a successful bombardment by field artillery occurred at Litchenberg, a small hill fort in the Vosges. It was attacked on the 9th of August by 2 battalions, ½-squadron, 3 batteries, and a detachment of engineers. The infantry got cover close

to the place in the village on the west, and in a wood on the east, the cavalry kept up communication between the two battalions, and the guns opened fire from the hills on the west. The engineers, under cover of the artillery and infantry fire, got into the covered way, blew open a gate in the palisades, and examined the ditch, which they found too deep for escalade. The fire of the artillery produced so little effect, that after some hours the attempt was given up, and the troops were ordered to retire, leaving only a battalion and the cavalry to watch and mask the place. Just at this time, a large building burst into flames—the result of the previous artillery fire—and one battery was ordered back at 7 p.m. to open fire again. Upon this the Commandant immediately capitulated. He was, however, a very young officer, a second lieutenant, and his garrison were chiefly fugitives from Wörth, so that the inference must not be drawn from the historical fact that such a mode of proceeding *ought* to produce such an effect; but that under similarly unfavourable circumstances for the defence it may possibly succeed, and, therefore, may be worth trying.

Very different was the result in many other cases, notably at Toul and Phalzburg, The former was bombarded first by two field batteries, while six battalions of infantry made a demonstration of attack. The infantry were soon forced to retire with loss, and the guns only succeeded in producing one small fire, which was easily extinguished. A week later, 12 field batteries bombarded again without any result. After this, repeated bombardments by field artillery, in greater or less force, were endured by the garrison, who, so far from giving in, made repeated sorties, and did much harm to the Germans by the fire from their heavy guns and mortars. At length after six weeks' investment, the Germans placed 26 siege guns in battery, and bombarded with them for a whole day, when the French gave in, having fired away all their ammunition. It is to be specially noted that Toul had hardly any bombproofs, and that the garrison were mainly composed of Mobiles; but the Commandant was a good soldier, and infused his spirit into those under him. At Phalzburg, a bombardment by 60 field guns, which fired in all 1,800 rounds into the place, produced no effect. Here there were bombproofs and traverses for the garrison, as well as a firm Commandant, but there was also a considerable civil population, who bore with much heroism the sufferings and losses of this first great bombardment, and of several minor bombardments during some of the nights of the investment, which lasted four months, until want of food compelled the garrison to surrender the place.

The Germans did not generally use field guns for bombarding at extreme ranges, they preferred getting within a mile of the place, in order that the result of the firing might be carefully observed, and accurate fire concentrated on any building seen to be in flames, so as to prevent its being extinguished. But should circumstances of ground, &c., make it desirable, the range might be increased to two, or even three miles. As regards projectiles there was a difference of opinion. Some German artillery officers expressed a strong opinion in favor of incendiary shells, others considered the common shell sufficient.

Surprise is only likely to succeed when the garrison is known to be careless, and when some means of access into the place is known to exist, or some weak point in the fortifications where an escalade may succeed. The stories of our exploits in the Peninsula are so well known that I will not refer to them, although the Duke of Wellington more than once resorted to this mode of attack. The Germans were not very enterprising in this way during 1870-71, but they did make one unsuccessful attempt at Thionville, which they afterwards reduced by bombardment with siege artillery. The ground on which the attempt was made was information obtained from a reserve cavalry soldier who had been a resident in Thionville, and at the outbreak of the war was employed on the defences of the place. He found means to escape, and to return to Germany and join his regiment in time to take part in the earlier battles; but while at Thionville he had noticed that there was a ford through an inundation, which was the principal defence at one point in the *enceinte*. The plan was to assemble a sufficient force at hand during the night to endeavour to obtain possession of the place by effecting an entrance by the ford. It might have succeeded had not the Moselle risen, and made the ford impassable; but the enterprise was discovered by the French before it was put into execution, and probably success could only have been obtained by a great sacrifice of life. In this case the force employed consisted of all arms, and doubtless this was right, for, although the real conflict inside the place must have been carried out by the infantry, aided by a few engineers to act as guides and to overcome obstacles, and a few artillery to spike captured guns or turn them on the enemy, yet, in case of a failure and retreat, or of there being a force camped outside the fortress, the cavalry and artillery would have had their parts to play.

I would only farther allude to the absolute necessity of a well

considered plan being arranged beforehand, and the exact duties of each body of troops concerned being clearly defined and made known to them in all such attacks. It was from the want of such pre-arrangement that we failed to reap the fruits of our successful entrance by surprise into Bergem-op-Zoom, the different columns of attack, having no orders what to do when they got inside the place, turned in opposite directions, and, becoming thus separated and confused, were beaten in detail and driven out by the French garrison.

The attack by storm may be preceded by bombardment, or may partake of the nature of a surprise; but its essential features are a forcible entry by either destroying or surmounting the obstacles, *i.e*, battering down with artillery, or blowing in the gates, or escalading the walls, while the artillery and infantry keep down as far as possible the fire of the garrison. A well constructed permanent fortification should be secure against open attack by storm, or "*sturm-frei*" as the Germans concisely term it. It is only imperfectly constructed fortifications badly defended that can be reduced by such means, particularly when the attack is a surprise.

Should such an attempt be determined upon as necessary, owing to the importance of the place, and the insufficiency of means and time for other and surer methods of attack, it is all important, as above observed, to have a good plan, and to let all concerned know exactly what they have to do.

Previous experimental practice in any special method of overcoming obstacles, such as escalading, or throwing flying bridges over ditches, will be of great advantage. Probably we have all heard of the French "Malakoff drill"—the previous practice which enabled them by means of flying bridges to swarm into the works so rapidly, and which was the key to their success. Further, either by plans of the works, by information obtained from spies or deserters, or by actual observation, the nature and dimensions of the obstacles to be overcome should be as thoroughly as possible ascertained before the storm is undertaken. In the attack on Belfort the Germans attempted to take by storm the detached works on les Perches. They had obtained French plans of the fortress, which showed these only as field works, and relying on this information they advanced to the attack without any means of crossing ditches—arrived at the counterscarp they found that the ditches were cut out of the white limestone rock of which these hills are formed, and although a number of men jumped in they were unable to get out again, and

were made prisoners by the French. One other condition, and a most essential one in all such undertakings, is the employment of a sufficient number of good troops. The Germans put it down as at least $2\frac{1}{2}$ to 3 times the garrison. Our failure at the Redan, on the 28th of September, 1855, is one of the many warnings against this miserable halting policy, as Sir John Burgoyne forcibly terms it, which fears to employ the means essential to victory, lest good troops should be sacrificed in a possible failure, and thus ensues failure, loss, and disgrace.

Blockade or investment is a slow but sure way of reducing a fortress, and the more mouths it contains the surer and quicker the process. It is also a necessary preliminary to a regular siege, and it may be combined with a bombardment by field or siege artillery. A force detailed for the investment of a fortress sends on in front by forced marches the cavalry and horse artillery, with whatever engineering means are organised for rapid movements to make the preliminary investment. Mounted riflemen would also be valuable for this service. Infantry transported in country wagons were sometimes employed by the Germans. The object of this preliminary investment is to drive in the cavalry outposts of the enemy, to cut their connection with neighbouring fortresses, or the seat of government by telegraph, rail, road, or water, to prevent supplies being taken into the place, and to prevent the destruction of bridges, &c., which favour the march of the investing corps. It is possible, of course, for the garrison to break this weak investment by infantry sorties, but, however active they may be, the cavalry investment is a serious evil to the garrison, and a valuable preliminary to the regular investment. One of its great uses is that by means of it a preliminary reconnaissance is made, existing maps are verified, advantageous camping grounds selected, and such a general knowledge is obtained of the environs, and of the state of the fortress and of the garrison, as will enable the general of the investing army to decide approximately on the positions to be occupied by the different corps in the investment, and to order their marches accordingly.

There was a case in the last war in which this preliminary investment was maintained for a considerable time. After the failure of the attempted *coup de main* on Thionville, and while the strength of the German armies was mainly devoted to dealing with the French armies at Metz, Sedan, and Paris, a regiment of lancers with a small detachment of engineers was left to invest Thionville. A four-horse coach was used to move the engineers

rapidly from place to place to barricade roads, fortify buildings, &c., on the circumference of the circle watched by the cavalry. At night the posts were pushed in close to the place, at daylight they withdrew beyond cannon range, and by ceaseless activity and remarkable boldness and skill these 600 lancers, reinforced by 300 hussars for part of the time, and always aided by their coach-load of sappers, so imposed on the garrison, which consisted of 2000 regulars and 3000 Mobiles, with some cavalry and field artillery, that they held them inside their works for six weeks until the arrival of the investing corps.

I do not think a bolder feat, or one of which the German cavalry have more reason to be proud, was performed by that excellent branch of their army during the war, and I mention it to show how, even in fortress warfare, cavalry may often find full scope for their action; but I would take this opportunity of saying, that this is only one of the many cases in which a combination of a certain amount of field engineering, with ordinary cavalry duties is now called for.

In order that cavalry may be able properly to perform such duties one of two solutions must probably be adopted. Either cavalry officers and soldiers must be trained in field engineering, and must carry on their horses the necessary tools and appliances, or else they must have associated with them, when ordered on duties requiring engineering means and knowledge, a proportion of horse engineers—as they have already horse artillery—of such a body the Thionville sapper four-in-hand may be taken as the embryo or type; while the cavalry engineers in full bloom are to be found as yet only in the Austrian service, where, under the energetic direction of a genius and enthusiast in his profession, the system appears to have attained to great perfection, and to work well.

Whichever plan may be adopted in our service, I only hope that it may be thorough—no playing at engineering will meet the case. That our cavalry officers and soldiers have the ability to perform such work, no one can doubt for a moment, and if they take it up *con amore*, and if their training and equipment for such field engineering work as they may be called on to perform, be as perfect and as much a matter for the annual inspection by the General, as their training and equipment for ordinary cavalry duties now are, one can foresee a new and most interesting future for this arm; but if on the other hand, it be looked on as a *spécialité* in the hands of a few initiated officers and men, and in which Commanding Officers take no intelligent interest, one may safely venture to predict that

it must inevitably prove a failure. Naturally being an engineer myself, my feeling is rather in favor of giving mobility to engineers, than of training and equiping cavalry to perform their duties. But I see, nevertheless, some advantages, particularly as regards unity of command, in the latter system, if it can be as thoroughly carried out as in the Austrian service, without impairing the efficiency of the cavalry for cavalry work.

But we must pass on to speak of more regular investments, which formed one of the most distinctive and most remarkable features of the War of 1870-71. Shortly before the outbreak of that War, a writer of note, whose work on the "Defence of States," is still a standard book, and whose genius has devised, and whose energy has mainly carried out, the modern system of the defence of Belgium —General Brialmont—devoted a chapter to prove that it was absolutely impossible to invest a great intrenched camp, and he cited Paris as an example of the value of such a fortress, impossible to invest, supremely difficult to reduce. I do not suppose that any one in Europe would have challenged the correctness of his conclusions before the stupendous events of 1870, except, indeed, those astute strategians at Berlin, who had evidently been able to realize beforehand, not only the possibility, but the comparative facility of such operations. And the flaws in General Brialmont's arguments are now evident enough. He based his conclusions, first, on the supposed impossibility of feeding, housing, and maintaining the enormous armies required for the purpose, at so great a distance from their own base, and for so long a time as would be necessary ; secondly, on the supposed advantage the invested army possesses, owing to its interior position, secured from the concentric attack of the surrounding enemy by its forts, while it is able to issue in force at any point of the circle, and to attack suddenly and unexpectedly with greatly superior forces, thus having always the power of the initiative, and of being the stronger at the point attacked, the acknowledged main elements of success in war.

The question of supply was solved by the Germans, by the skilful use of railways, and of their Etappen system, of which I will say no more, as Lieut.-Col. Home discusses this subject.

But the question of exterior *versus* interior position is so interesting and important that I must devote a few minutes to it.

The universally accepted laws of strategy teach us, that when opposing armies in several distinct fractions are manœuvring at a considerable distance apart from one another, that army whose

fractions can most readily combine to attack one of the isolated fractions of the other, has the immense advantage always claimed for interior compared with exterior lines or positions. When, however, the armies are so near that the whole of one army is menaced or attacked by the fractions of the other army, within supporting distance of one another, the concentric attack of the armies on exterior lines, probably succeeds. The moment we pass from the realm of strategy to that of tactics, the advantages formerly appertaining to the interior or central position, have passed over to the other side. Should the army in the interior position, however, be supported by the fortifications of an intrenched camp, the question is considerably altered, for, in the first place, the concentric attack of the exterior armies, even if very superior, cannot strike home, being arrested by the fortifications; and if there be a near approach to equality between the opposing armies, that which is in the interior position, not only is unattackable by the other, but under certain circumstances it has a great opportunity of inflicting a crushing defeat on the army outside, because the forts protect its rear, or its flank in offensive movements, and its interior position, and presumed good and short communications enable it to manœuvre so much more rapidly than the army outside, as to be always stronger than the force opposed to it, whenever it strikes outwards.

All this is still true as it was in former days, but the great power of long resistance to attack in front by greatly superior forces, conferred by improvements in fire arms, here comes fully into play. The investing army presents an unbroken front with no flanks to be turned, and wherever the invested force attacks, it must always itself be outflanked, and be under the necessity of making a frontal attack. The question then arises how many men can be employed with advantage, per mile of front, in a purely defensive action. Whatever this number may be, if the investing force can only dispose of so many troops all round the circle, with reserves in convenient positions to be brought up to reinforce any part of the line which may be hardly pressed, the task of the army inside, in any attempt to break out, becomes extremely difficult, for, whatever numbers it may be able to bring to bear on any part of the circumference, no more men can be employed in the shooting line in front than are opposed to them—in fact, not so many—as, on whatever extent of front the attack be made, the front of the investing defender must extend beyond it on both flanks. In the days of shock tactics, columns of attack would burst through the thin line, but in these

days of fire tactics, the thin line is too strong for the column. All that the attack can do is to melt away the line at the point of attack, as it also melts away itself by the fire action on both sides, and being able to supply the losses of its own front line without stint, while the investing line has only weak reserves at hand; in course of time a gap is made, and the stream pours through. But in the first place the *time* required to overcome the resistance of the investing line at any point is now considerable, and a well arranged investing line consists of three concentric circles, the outpost line intended to stop small sorties, and to delay great ones, then the main position, and finally, rallying positions in rear. The resistance offered at these successive points must always cause great delay; if they have been fortified, the time required to force them, whatever numbers may be employed, is greatly increased, and, during all this time, reserves are brought up from the flanks and rear. Moreover, should the invested troops succeed in forcing their way through, and break out, it will be only to find themselves in the disadvantageous position of being attacked on both flanks and in rear, without the support of fortifications, and without the possibility of taking any train of supplies with them, until the investing force has been completely beaten and driven away.

It is true that successful sorties in force may be of great value to the defence. When they have a definite aim, such as to gain some vantage ground, which will greatly extend the investing line, for instance, the high ground commanding the passages of the Moselle, at Malroy, above Metz, or to destroy or get possession of the depôts of the investing force, for instance, the railway station at Courcelles, which would have fallen into the hands of the French, had their sortie of the 31st August been carried out to its legitimate conclusion, however imperfectly commenced; or finally, to save a portion of the invested force from reduction by famine, and to prolong the resistance of the remainder; as, for instance, had Bazaine broken out with two of his corps northwards, and gained Thionville, and thence, if necessary, the Belgian frontier, so saving part of his army, and by diminishing the number of mouths, enabling the rest to hold out longer.

We see then the present state of the question, as regards the value of intrenched camps or permanent fortified positions, to be this. For their owners, primarily, the protection of an army unable to cope with the enemy in the field, obliging him to invest them with a force considerably larger, and so neutralising this force during the period

of the investment. In a secondary way, giving the invested force a chance of obtaining, at least, partial success, by large sorties, particularly at the beginning of the investment, if it be not skilfully and carefully conducted. But on the other hand, although the long ranges of rifled guns keep the invester at a greater distance than formerly, railways and rifled breechloading small arms enable him to maintain the enormous armies required for the purpose, and to hold the long line of investment with comparatively weak forces.

Let us review for a few minutes the tactics of both sides in the war of investment. An investment can only take place when the investing is so much stronger than the invested side, that the armies of the latter cannot keep the field in the presence of the full strength of the former, and have either been driven away from a fortress which is defended by its proper garrison, as was the case at Belfort, or have been forced to take refuge in it, as the result of a lost battle, as at Metz; or it may be simply the result of the evident superiority of one side forcing the other to take refuge behind fortifications, as would probably be the case at Antwerp, were Belgium to be invaded by France or Germany. The investment of a fortress which does not at the same time shelter an army, and thus become a fortified position, is evidently easier than the latter, and the tactics of attack and defence in the two cases will be somewhat different.

In the defence of a great fortress by its own garrison, it is clear that the first endeavour should be to obtain information of the enemy's movements, and to check his preliminary investment; in both of these duties the cavalry have their *role* to perform. The investor, on the other hand, with a superior force of cavalry, forces the invested cavalry within the line of infantry outposts which will probably be 1000 yards in advance of the forts.

Should an army be sheltered by the fortress, the preliminary investment will probably be impossible, as a considerable force of all arms would be maintained outside the girdle of forts, to prevent any such attempt, and to harrass and obstruct the advance of the investing army.

The mode of bringing up the troops for the investment, and of moving them into the positions they are to occupy, requires careful forethought, if an army is to be enclosed; as any unwise division of the forces during the process of filing into their positions, might be taken advantage of by the army to be invested with disastrous results to the investor. As in all military operations, no exact rules can be given, because circumstances vary infinitely; but the general

idea of such an operation is that the different corps of the investing army advance in concert, on the same side of the fortress, the advanced guards of the troops deploy, and drive in the enemy's outposts until they come under fire of the fortress artillery, then the advanced guards take up the best positions they can to resist a counter attack, while the main bodies move up into their appointed positions. Each successive corps in its encircling march, moves in rear of, and covered by, a corps already in position; thus the deployment is continued probably from both outer flanks of the roads by which the general advance has been made, until the forces join hands on the far side. Probably, however, the operation will not be completed without a general action, in which the force to be invested may derive the greatest assistance from its fortifications, and the would-be investor may find the task too hard for him.

Supposing, however, that the circle is completed, in order that unity of design may exist in the investing arrangements, an engineer reconnaissance is made as early as possible, completing, it may be, a previous cavalry reconnaissance, and on the information and recommendations so obtained, the General commanding issues the orders for the positions to be occupied by each corps. These positions may vary somewhat in extent according to the character of the terrain, and the comparative strengths of the forces inside and outside the fortress. As before mentioned the investment is arranged in two or three, or even more, concentric lines. The outpost line can seldom be nearer than from 1 mile to $1\frac{1}{2}$ miles from the forts, the main line about $2\frac{1}{2}$ to 3 miles, the rallying position about a mile farther to the rear; the general line of the main positions is indicated by the General commanding, but the details are left to corps commanders. The extent of each section will vary between the allowance of 3,000 to 7,000 infantry per mile. At Metz, where a regular army was enclosed, an average of about 7,000 infantry per mile, in addition to cavalry and field artillery, were considered necessary by the Germans, but in some cases the number was as high as 10,000, in some as low as 5,000. At Paris, the average was a section of about 5 miles to an Army Corps, or, 25 battalions, with 14 batteries, and 8 squadrons; giving from 4,000 to 5,000 infantry to the mile. The ordinary number of troops required for the investment of a fortress, *not* enclosing an army, is generally laid down at about three times the garrison, and this would generally suffice. Take Metz as an example, the perimeter of the entrenched camp there is about 15 miles, the diameter about 5

miles; the main position of an investing army must he about $2\frac{1}{2}$ miles outside this, or be a circle with a diameter of 9 or 10 miles, and a circumference of 25 or 30 miles. Practically the German positions extended for 27 miles.

The garrison the Germans allot to this fortress is 40,000 men; three times 40,000 men = 120,000—the number that would theoretically be required to invest them. These 120,000 distributed over 27 miles, would give an average of about 4,500 men to the mile; which probably is a minimum, if regard be had to the necessary fatigue and exposure of the men. If on the other hand, an army of 60,000 men were taking refuge in the entrenched camp, bringing up the total to 100,000, the investing corps must be stronger, but not 300,000, which would be in the same proportion as before. It would, no doubt, be necessary to increase the force to about 5,000 men to the mile, which would give a total of about 135,000; while, should the army taking refuge be 120,000 men making a total of 160,000; (a little less than the French had in Metz) the investing corps need not be much superior to it. Even the maximum of 7,000 men to the mile would only bring up the numbers to 190,000.

The principle involved, has already been alluded to, only a certain number of men per mile can be employed to shoot at one time; if these exist with sufficient supports and reserves to fill up casualties, and recover ground lost by any failure on the part of the investing troops, *no* numbers that can be massed to attack in front, are of any avail. It is indeed almost proved by the events at Paris, that an average of 5,000 men to the mile on the investing line, is sufficient to keep in *any* number that may be inside, even considerably superior to their own, as was the case towards the end of that investment, but the indifferent character of the troops inside, makes it somewhat hazardous to argue from this example.

On these principles, then, the necessary strength for an army of investment is determined, and the line apportioned out amongst the different corps composing it. Wherever natural obstacles bar the egress of the troops inside, these may be watched mainly by cavalry, as the loops of the Seine were, below Paris. The field artillery is placed generally, in the main position, commanding all the roads leading out of the fortress, and the open ground where troops may be massed for attack. Occasionally some guns may be further advanced, but as they cannot contend with the fortress artillery, it is better to keep them out of their effective range. The duties of the troops are so arranged that they take the outpost duty in turn.

In the investment of Paris, each army corps had one division on duty each week, the other off duty; and of the division on duty, one brigade was in the outpost line, the other in reserve, in the main position on alternate days. The artillery and cavalry were generally in reserve, one or two batteries, and a squadron being always on duty in the main position.

The works to be performed by the troops, are, first the fortification of the outpost line, then that of the main position, and the improvement of communications of all sorts, the hutting of the troops on duty, and finally the preparation of the rallying positions. It is evident that the method pursued at Paris, where the positions at first assigned to the various corps were not altered throughout the duration of the investment, is very much to be preferred to the plan adopted at Metz, where the troops were continually being moved, according to the varying circumstances of the war, and the supposed intentions of the French, and which resulted, not only in very unnecessary fatigue and annoyance to the troops, but, in fact, was the main cause of the French success on the 31st August; as the part of the line they attacked, was then almost denuded of troops, which had been moved to meet an expected attack on the west. In the case of a strong investment, no reserve corps appear needful; but in the case of a weak investment, of say, only 3,000 men to the mile, it would appear advisable to have a strong reserve to every two or three sections of the investing line, that is to ten or fifteen miles.

The character of the outpost line would generally be as far as possible, a continuous line of obstacles, under direct and flanking infantry fire from the infantry posts at all the strong points in it; piquets and sentries in front of this line, sheltered as well as possible, and always altering their position at night, and patroling well to the front. In the main position, only such fortifications as will not interfere with the counter attack, which must be delivered to regain the outpost line, should the enemy succeed in forcing it.

Let us glance now at the duties of the invested; whether it be a fortress with only its proper garrison, or whether an army be taking refuge there also, the general plan assimilates to that of the investor. The circumference to be defended is divided into sections entrusted to corps, divisions, or brigades, who are responsible for their own sections, and in each of which there is a proper rotation of duty, special garrisons being always detailed for the forts. Without entering into any of the details of the defence, I would only allude

to the two subjects of outposts and sorties. The distance in advance of the forts, at which the defenders can maintain their outposts, depends, of course, on many circumstances; but unless these be very unfavourable to the defence, they ought to be on an average 1,000 yards in advance, as long as the artillery in the forts is unsilenced, and in many cases they may be still farther to the front; they should not be connected by obstacles wherever sorties are intended, as these would be hindered by such accessories, but between the forts in the main position the line should be made continuous by fieldworks, openings being left close to the forts, and this line of fieldworks would be the eventual position for the main artillery defence, in case of a siege. Thus the outposts act as an outer line of detached forts, while the forts connected by fieldworks, form an outer *encéinte*, and the enemy is pushed out one step farther from his object. Small sorties should be made systematically, at night, in all directions at irregular hours so as to keep the investing troops on the alert, and to weary them out.

Sorties in force should only be made for definite objects as before mentioned, and the plan should generally be somewhat as follows: The troops intended for the attack, should be assembled during the night, as near to the point of attack as possible, secretly and noiselessly. The advanced guards attack, and carry by surprise the investing outposts before daybreak, and followed closely by their supports and reserves, push on as rapidly as possible to the main position, so as to traverse the zone of artillery fire, and to gain all the ground possible before daybreak; then a combined attack, fully supported by artillery on the enemy's position to be won, and on the positions right and left of it, for it must be borne in mind that reinforcements for the part of the line attacked are most quickly obtained from the adjoining corps, and that, consequently, if the real attack be made, let us say, northwards, the false attacks should be made to the east and west, rather than to the south, although a preliminary small sortie to the south might serve to mislead the enemy, who would probably hear some sounds of movement, and be somewhat on the alert.

Points won must at once be intrenched, of which we have a successful example in Ladonchamps—won, intrenched, and permanently held by the French in one of their sorties from Metz.

Should an army be forced by inferiority, to take refuge in an intrenched camp, it may have a great opportunity of defeating a

superior force, by fighting in its prepared position, where it has everything in its favor, and can but be invested, if defeated.

The possibilities of successful manœuvring for an inferior force, aided by a permanent entrenched camp, have never yet been exemplified; but there is here, a great field for skilful generalship, and we may expect to see its results in any future European war; but when once shut inside the fortified lines of investment, an army has little hope of escape, unless aided from without.

As regards this external aid, an investing force used to protect itself by lines of circumvalation; but such a method would be quite unsuited to modern requirements. Relieving armies must be met and beaten at a distance from the fortress by a covering army, and the lines of communication for supply of the investing army, must be protected. Sometimes several such covering forces may be needful, as at Paris in 1870; by the free use of cavalry, and of the electric telegraph, it has become possible to combine and direct the action of these different armies, so as to neutralise any efforts at relief, unless made in overwhelming force, and with great skill, the covering armies occupying, strategically, interior positions with reference to the relieving armies.

Our time draws to a close, and I must confine myself to a few remarks on bombardment and sieges.

The humanity of the former mode of proceeding has been doubted and its efficacy has been sometimes over-rated. There can, however, be no question that a fortified place must be subjected to the rigours of war. It is usual at the beginning of an investment, to allow any civilians who may desire it to leave the place—after that they must stand or fall with it; and as regards actual loss of life, the statistics of the last war seem to prove that the famine and privation endured during a long investment, are far more destructive to the inhabitants of a town than a bombardment. The theory of a bombardment is that the constant bursting of shells, and the conflagrations, deaths, and wounds caused by them, produce such a state of horror and nervous terror, that human nerves cannot bear the tension beyond a certain time, and so a capitulation is forced on the Governor by the civil population. The bombardment of a fortress which does not take effect upon a town enclosed, and in which the garrison have sufficient bomb-proofs, produces no result. But the regular bombardment by siege artillery, of one of the old fortresses enclosing a town, was a mode of attack which proved irresistible in the last war. The noteworthy points are the slow rate of fire maintained by the

Germans in such operations—not more than four rounds an hour by day, and one by night, from each gun; and the excellent system of siege artillery, with all its appliances, and organisation of men and material, which exists in the German service. At present we have nothing to compare with it.

A siege becomes necessary when none of the easier methods are sufficient to reduce a fortress. No good modern fort or fortress ought to be reduced without a siege. We are still without examples of a modern attack on a good modern fortress—and the details of a siege are too technical—too much the acknowledged province of the artilleryman and the engineer to come within the scope of the present lecture—but I will just indicate the general principles of the operation in its modern form; first comes the investment, and while the siege train and the special siege corps are being brought up, preparations are made for the intended operation as far as possible by the collection of siege materials—gabions, fascines, timber, &c., in which all the troops off duty are employed. The choice of the front for attack, is now mainly influenced by the means of transport; and no large inland siege can be undertaken without the aid of a railway to transport the enormous quantities of ammunition required. At Strasbourg, more than 150 tons were fired away every day. The old calculations for the strength of a besiging army hardly hold good now, and the mode of attack has altered considerably. The investing force is the primary consideration; the siege corps proper strengthens the investment on the side to be attacked, and has attached to it a sufficient proportion of garrison artillery and engineers, to work the siege guns, and to make the batteries, saps, and mines. The siege proper opens by an artillery attack with siege guns in battery, at ranges of from 3,000 to 4,000 yards, to silence the fire of the fortress, and to enable the outposts of the investment, under cover of which the batteries were built, to drive in those of the defender, and the first parallel to be established. This would probably be about 800 yards from the place, and is the first infantry position from which marksmen can fire accurately at the defenders if they show themselves. A second artillery position is then prepared at from 1,000 to 1,500 yards from the place; and a more complete effect is produced on the defences. The advance to the fortress is then carried forward under support of these batteries, much in the same manner as formerly, except in the details of saps which I will not here discuss.

The formation of breaches and the silencing of flank defences of

the ditches, will now be effected in most cases by curved fire from batteries not nearer, probably than 800 yards. Batteries on the crest of the covered way would be so difficult to make, arm, and work, under the close fire of modern rifles, that probably mines will be used for the close attack, when the necessary results cannot be obtained by artillery fire.

In the defence the great feature of modern fortress warfare, is the constant construction, and unexpected opening of new batteries between the forts; to silence these has been found much more difficult than to keep under the fire from the forts themselves. At least two of the detached forts must be taken, and the adjoining ones silenced before the interior *encéinte* can be attacked. If this be sufficiently far from the object to be defended or gained, to make a bombardment from the position of the forts unlikely to produce the desired effect, a second siege must be commenced to get into the *encéinte*; but in most existing fortresses, when once the detached forts have been taken, a bombardment will complete the work, as the vital point is then within range.

I have now touched briefly on a few of the most important features of fortress warfare, and however imperfectly my task has been performed, I trust that it will be admitted, as a fair conclusion, that this special phase of fighting holds at least as important a place in modern warfare as it has always had in former times, and that a thorough knowledge of the use of fortresses, and of the ways in which they may be employed or neutralised, is most essential to officers of all branches of the service, while to statesmen and strategists, generals and their staff, they present some of the most interesting and difficult problems of war. To artillerymen and engineers, the subject is, of course, vitally important, and the details in many points are still imperfectly worked out in our service; notably, I may venture to mention, good carriages for siege guns, and for garrison guns to be served on open ramparts, which will do away with the old embrasure, now obsolete, owing to the accuracy of modern firearms.

HENRY SCHAW,

LT.-COL., R.E., AND BT.-COL.

PAPER XV.

FORMULÆ FOR

SUSPENSION BRIDGES.

By Lieut. F. R. de Wolski, R.E.

In Appendix B to Captain Fraser's paper on Suspension Bridges, in *The Professional Papers of the Royal Engineers*, Vol. XXII., will be found the results of experiments to ascertain the tension and deflection of a heavy rope, loaded with a weight at its centre. On referring to Table II. of these experiments, it will be seen that the calculated stresses are considerably in excess of those actually recorded by the dynamometer. The formula employed in the calculations—

$$\text{Tension at either pier} = \tfrac{1}{2}\sqrt{L^2 + \frac{a}{4d}(L + W)^2}$$

where L = total load on rope,
„ W = concentrated load at centre,
„ a = span,
„ d = droop of rope due to its own weight only,

assumes that the horizontal tension caused by a concentrated—in addition to an uniform—load is equal to that which would be produced by an uniformly distributed load of twice the concentrated load added to the uniform load, the tension at the piers being the resultant of half the actual total load and this horizontal tension. This distribution of the load is applicable to beams; it does not hold good in the case of a span of rope.

The object of this paper is to show that the problem admits of correct solution in a form convenient for calculation. The only assumption made is that in the ordinary forms of suspension bridges the proportion of droop to span is so small that the weight

of the rope may be treated as an uniform load, distributed along a horizontal line. The curve assumed by the rope will then be parabolic.

The problem to be solved, in its simplest and most generally useful form, may be stated as follows :—

Given the span, droop, and weight of a heavy, inextensible rope, suspended between two points in the same horizontal plane, to find the tension at the points of support, and also the depression of the rope, when a given load is hung from its centre. (See *Diagram* 1.)

The concentrated load W at the centre of the rope ADB, causing it to assume the position AGB, may be replaced by its own weight of the same rope. Let JG be this length of rope. Bisect it in E. Then E is the lowest point of a parabola MJEGOB, in which the tensions are the same as those in the curve AGB. Further, as the rope is inextensible and of fixed length, the curves DB and GB are of equal length.

$$EG \times w = EK \times w = \frac{W}{2} \text{ (by hyp. and const.)}$$

$$\therefore EK = \frac{W}{2w}.$$

Similarly,
$$EF = EK + KF = \frac{W}{2w} + \frac{a}{2}.$$

$$\therefore EF = \frac{L}{2w}.$$

Again,
$$BF : GK :: EK^2 : EF^2.$$
$$y : y' :: W^2 : L^2.$$
$$y' = y \times \frac{W^2}{L^2}.$$

Now length of curve $BD = \frac{a}{2} + \frac{4d^2}{3a}$,

and " " $EG = EK + \frac{4y'^2}{6 \times EH}$,

" " " $= \frac{W}{2w} + \frac{4y^2 w W^3}{3L^4}$.

But " " $EB = EG + GB = EG + DB$.

" " " $= \frac{W}{2w} + \frac{4y^2 w W^3}{3L^4} + \frac{a}{2} + \frac{4d^2}{3a}$.

Also " " $EB = EF + \frac{4y^2}{6\,EF}$.

" " " $= \frac{L}{2w} + \frac{4y^2 w}{3L}$.

Equating the values of EB, we get,

$$\frac{W}{2w} + \frac{4y^2 w W^3}{3L^4} + \frac{a}{2} + \frac{4d^2}{3a} = \frac{L}{2w} + \frac{4y^2 w}{3L}.$$

$$y^2\left\{\frac{4W}{3L} - \frac{4wW^3}{3L^4}\right\} = \frac{a}{2} + \frac{4d^2}{3a} + \frac{W}{2} - \frac{L}{2w}.$$

But $$\frac{W}{2w} - \frac{L}{2w} = -\left\{EF - EH\right\} = -\frac{a}{2},$$

$$\therefore y^2 \times \frac{4W}{3}\left\{\frac{L^3 - W^3}{L^4}\right\} = \frac{4d^2}{3a};$$

$$y^2 = \frac{d^2 L^4}{wa(L^3 - W^3)};$$

$$y = \frac{dL^2}{\sqrt{wa(L^3 - W^3)}};$$

But $$y = y' \times \frac{W^2}{L^2};$$

$$\therefore y' = \frac{dW^2}{\sqrt{wa(L^3 - W^3)}}.$$

Depression DG $= y - y' - d.$

$$\text{,,} = \frac{dL^2}{\sqrt{wa(L^3 - W^3)}} - \frac{dW^2}{\sqrt{wa(L^3 - W^3)}} - d.$$

$$\text{,,} \quad \text{,,} = d\left\{\frac{(L^2 - W^2)}{\sqrt{wa(L^3 - W^3)}} - 1.\right\}$$

$$\text{,,} \quad \text{,,} = d\left\{\frac{L + W}{\sqrt{L^2 + LW + W^2}} - 1\right\} \quad \ldots\ldots\ldots [1].$$

In the triangle of forces BNF,

$$BF : NF :: \frac{L}{2} : H$$

$$y : \frac{L}{4w} :: \frac{L}{2} : H$$

$$\therefore H = \frac{L^2}{8wy} = \frac{L^2\sqrt{wa(L^3 - W^3)}}{8wdL^2}.$$

$$\text{,,} = \frac{\sqrt{wa(L^3 - W^3)}}{8wd} \quad \ldots\ldots\ldots [2].$$

Tension at either pier $= T = \sqrt{H^2 + \frac{L^2}{4}}.$

$$\text{,,} \quad \text{,,} = \sqrt{\frac{wa(L^3 - W^3)}{64w^2d^2} + \frac{L^2}{4}}.$$

$$\text{,,} \quad \text{,,} = \tfrac{1}{2}\sqrt{\frac{a^2}{16d^2}\frac{(L^3 - W^3)}{(L - W)} + L^2}.$$

$$\text{,,} \quad \text{,,} = \tfrac{1}{2}\sqrt{\left\{\frac{a}{4d}\right\}^2 (L^2 + LW + W^2) + L^2} \ldots [3].$$

The formula used by Captain Fraser, when put in the same form is :—

$$\text{Tension} = \tfrac{1}{2}\sqrt{\left\{\frac{a}{4d}\right\}^2 (L^2 + 2LW + W^2) + L^2}.$$

The formula for the length of rope, from which the ordinates are calculated,

$$s = a + \frac{8\,d^2}{3\,a}.$$

gives a result which is an extremely close approximation to the true length of the catenary. The error in length is only $\frac{1}{8720}^{\text{th}}$ of the span (less than the true length) of a catenary with a droop of $\frac{1}{11}^{\text{th}}$, and $\frac{1}{3240}^{\text{th}}$ of the span (greater than the true length) for a similar parabola.

Example on page 182, Vol. I., Part 3, *Instruction in Military Engineering*.

$a = 200$ $\qquad$ W = 7·5 tons.

$d = \frac{1}{10} \times 200 = 20$ $\qquad$ $w\,a$ = 8·0 „

$\qquad\qquad\qquad\qquad$ L = 15·5 „

$$\text{Tension} = \tfrac{1}{2}\sqrt{\left\{\frac{a}{4d}\right\}^2 (L^2 + LW + W^2) + L^2}.$$

$$= \tfrac{1}{2}\sqrt{\frac{25}{4}(240 + 116 + 56) + 240}.$$

$$= \tfrac{1}{2}\sqrt{2820}.$$

$$= 26{\cdot}56 \text{ tons.}$$

The formula in the manual, the same as that used by Captain Fraser, gives :—

$$\text{Tension} = \tfrac{1}{2}\sqrt{\frac{25}{4}(240 + 232 + 56) + 240}.$$

$$= \tfrac{1}{2}\sqrt{3546}.$$

$$= 29{\cdot}8 \text{ tons.}$$

The difference is $3\frac{1}{4}$ tons, or 12% in excess.

$$\text{The depression at centre} = d\left\{\frac{L + W}{\sqrt{L^2 + LW + W^2}} - 1\right\}$$

$$= 20\left\{\frac{15{\cdot}5 + 7{\cdot}5}{\sqrt{412{\cdot}75}} - 1\right\}$$

$$= 20 \times \frac{2{\cdot}7}{20{\cdot}3}.$$

$$= 2{\cdot}66 \text{ feet.}$$

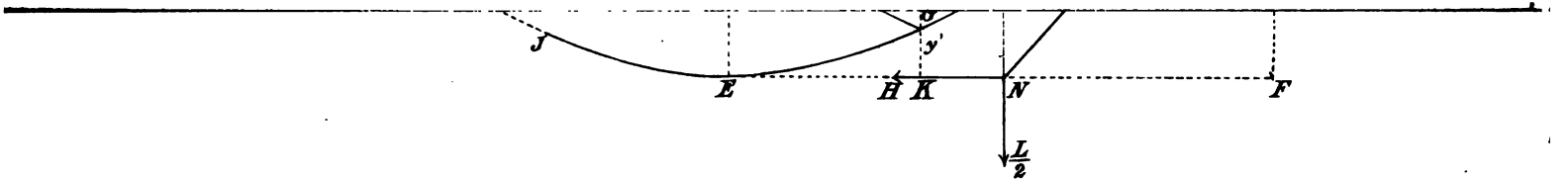
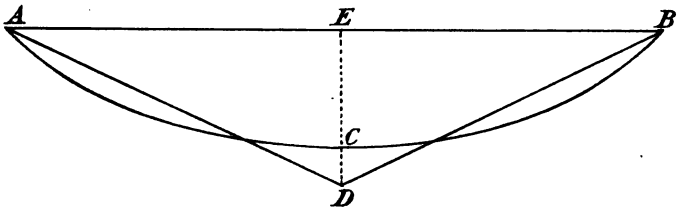


Diagram 2.



Application of Formulæ 1 and 3 to Table II., page 64, *R.E. Professional Papers*, 1874, Vol. XXII.

$a = 127.$ $\qquad w a = \frac{127 \times 40{\cdot}6}{6} = 860$ lbs.

No. of Experiment.	Dip of Cable.	Depression.		Concentrated Load.	Tension of Rope.		Percentage of error.
		Measured.	Calculated.		Measured.	Calculated.	
VIII.	$\frac{1}{10}$th	1·28	1·350	406	1848	1991	7·7%
IX.	,,	1·72	1·722	910	2815	3080	9·4 ,,
X.	$\frac{1}{15}$th	1·00	1·104	406	2397	2352	1·8 ,,
XI.	,,	1·43	1·432	910	3725	3649	2·0 ,,
XII.	$\frac{1}{16{\cdot}7}$th	1·70	0·940	610	3780	3955	4·1 ,,
XIII.	,,	1·80	1·031	910	4424	5006	13·0 ,,
XIV.	,,	2·25	1·055	1022	4648	5408	7·7 ,,

In Experiments XII., XIII., XIV., the measured depressions and tensions do not agree with those calculated, because the cable has evidently slipped.

$$\text{Length of rope} = 127 + \frac{8 \times 127^2}{3 \times 16{\cdot}7^2 \times 127}.$$

$$= 128{\cdot}2144.$$

The maximum droop of cable would occur when the curve ACB (see *Diagram* 2) became depressed at its centre until AD BD were straight lines.

Then, $$ED = \sqrt{\frac{(128{\cdot}2144)^2}{2} - \left\{\frac{127}{2}\right\}^2}$$

$$= 8{\cdot}8.$$

Hence the maximum depression = CD,

,, ,, ,, $= 8{\cdot}8 - \frac{127}{16{\cdot}7}$,

,, ,, ,, $= 1{\cdot}195.$

The depressions observed, viz.:—1·70, 1·80, 2·25, are, therefore, impossible if the rope remained fixed, and did not stretch.

F. R. DE WOLSKI,

LIEUTENANT, R.E.

PAPER XVI.

ON THE NAVAL

ATTACK OF A FORTRESS.

By Commander C. Bridge, R.N.

A Lecture delivered at the R.E. Institute on 26th June, 1877.

It was not, I may assure you, without much diffidence and many misgivings as to my ability to treat the subject properly, that I accepted the proposal of your Secretary, and agreed to deliver here a lecture upon so important a question of war as "The Naval Attack of a Fortress." It is only respectful to the Members of this Institution, and becoming in me, to lay before you some of the thoughts which filled my mind when I was honoured by the invitation to appear here this evening in the capacity of a lecturer. The place which I have to-day undertaken to fill, but too unworthily, is that from which have spoken men of great ability and wide repute, not only to the officers of your own distinguished arm, serving, as your motto claims, throughout the world, but also to the students of the science of war of every service and of every country. To attempt to occupy the chair from which they have taught, with increased credit to themselves, and advantage to the many desiring to learn of them, is indeed, to essay the armour of Achilles, or perhaps even to imitate the impious audacity of Phaëtôn. But another, and perhaps even a greater difficulty has to be confronted by one, who like myself, comes forward to address you on a military subject which he has not, during any great length of time, made his especial study. He is somewhat in the position of an amateur addressing an audience of experts. To your branch of the profession of arms belongs much of the credit of having raised the conduct of war from a rude barbarian art to the elevation of a great science; of having

directed some of the nobler of the moral and physical qualities of mankind, before wasted in senseless and unending conflicts, by methods matured after long thought and justified by a philosophical and scientific adaptation of means to ends desired. The difficulty of warlike operations has thus, through your instrumentality, been enormously increased, but the dignity of conducting them has thereby attained a commensurate augmentation. In the attack upon strong places this is especially the case; and the progress in fortification, and the increase in the power of defence in recent years, has fairly kept pace with the development of the methods of assailing them.

Within the last fifteen years we have seen the construction in our own country of vast works of defence, imposing in design, and so formidable in armament, that—when supplemented by the terrible secrets of torpedo-obstruction—they may well seem to give an impregnable security to the arsenals and dockyards which they have been erected to defend. An ancient article of the Military creed—that the ultimate advantage always rests with the attack—has thus received a severe shock. The labours which have rendered illustrious the names of more than one officer of the Royal Engineers have gone far to prove that the defensive capabilities of coast-forts are practically illimitable, whilst the offensive powers of ships and guns are finite, and perhaps their summit is now nearly reached. It is the business of officers of the service to which I belong to prevent the establishment of this proof. We are called upon to show cause why the Commander of a powerful fleet should not sit down with folded arms before a maritime fortress which the skill of Engineers has rendered formidable and difficult of attack.

You, Royal Engineers, who make it an occupation to work out the difficult problems of warfare, who see in the very difficulties of such problems fresh reasons for investigation and experiment, you would suppose that we naval officers are intent upon discovering some system of overpowering the strong-holds which every country with a sea-board has erected upon its shores, and of upholding the threatened superiority of the attack. Belonging to a fleet which has no equal upon the seas, it would appear to be one of our most pressing duties to devise means whereby we might prevent a rival, weaker on the ocean, from redressing the balance of inferiority by withdrawing his ships within the friendly shelter of his fortified harbours. The history of the naval operations in recent wars clearly indicates the great importance of so doing. Venice preserved by Austrian

Engineers in 1859; the numerous conflicts in the estuaries and rivers of North America during the Civil War; French iron-clad squadrons kept riding idly without the barriers of the North-German ports; not to speak of our own experience at Sebastopol and in the Baltic; all of these corroborate the view that to effectually crush an enemy's navy we must be able to capture or destroy the maritime fortresses within which his ships might take refuge. Yet towards this we have done little. Since our great victories in the early part of this century the study of naval tactics has been unaccountably neglected amongst us, and those who have of late essayed to revive it have either not thought it necessary, or have not yet felt able to go so far as to ascertain the system best adapted to a naval attack upon a fortress.

If there be one operation of war which more than another seems capable of being reduced to a fixed system, and being brought into obedience to definite and somewhat rigid rules, it is the attack upon a fortified place. The labours of a siege have been laid down in the text-books with nearly the accuracy of an almanac; and, given but the plan of the fortress to be attacked, the military engineer professes to teach the assailant not only the time required to make himself master of the place, but the occupation of his forces from day to day as well. This exactness we cannot hope to introduce into the system of attack to be undertaken by a fleet of ships. Steam has indeed in many ways rendered us almost independent of the winds and waves, but we are not yet in a position to disregard all meteorological considerations.

In discussing the manner in which a naval force can most profitably attack a maritime fortress we should recollect the remarkable situation in which the recent progress of the art of war, both by land and sea, has placed us. We find ourselves provided with new weapons, new armaments both of offence and defence, whilst at the same time we are almost without any practical experience of their use. So rapid has been this progress, that even the recent lessons of the war between the Northern and Southern States—almost the only ones in which we can hope to learn anything—are rapidly becoming obsolete. Changes in land warfare have been great since we last engaged in conflict with a European power; in maritime warfare there has been not so much a change as a revolution. Past experience and lessons of former times avail us little in forecasting the work that a future contest would demand of our seamen and our ships.

Yet, underlying this changed condition of things are intimations of great strategical laws which remain valid till now, and which will continue in force for all time. And beside this, the spirit of inquiry, which so distinguishes this age of ours, has attacked also the operations of war; and the result is a record of a long series of experiments which go far to enable us to estimate correctly the value of modern appliances for attack and for defence. In some cases these have been so complete as to be capable of being formulated; and we may now apply to the mechanics of warfare the rigorous methods of mathematical science. So that if we take up the ancient laws of strategy, embalmed for us in the story of many a deed of arms, and examine them in the light cast by the experimental knowledge of the last dozen years, we shall be able to arrive at some conclusions as to the conduct of a naval force operating against a fortified place. This, and this only, is what I can attempt to do here. To discourse fittingly of this important subject would require the limits of a treatise rather than that of an afternoon lecture.

Maritime fortresses may be roughly divided into two great classes: 1st, those which are complete in themselves and derive no benefit from the topographical and hydrographical conditions of their site; and 2nd, those of which the defences are strongly supported by positions for outlying works, and by the intricacy or shallowness of the channels of approach. Of these, Gibraltar may be taken as a capital instance of the first, and Portsmouth of the second. The latter, indeed, may be further sub-divided into fortresses on or near the coast, and those which line the banks of rivers or the shores of inland waters, such as the forts on the lower Mississippi, and at the entrance to Mobile Bay. Those of the last specified kind are—as a class—the least important of the three, and we are here enabled to appeal to experience as going far to prove that the passage of them can be forced by a strong and vigorous enemy. It is work something of this kind, which, at the beginning of a war, especially of a war with some partially Europeanised power, such as is often more or less imminent, that our navy would probably be called upon to do. But for the skill and patience with which the negotiations with China were conducted during the last complication, we might have found ourselves called upon only a few months ago to solve the question of passing a riverine fortress in the teeth of its garrison's efforts to stop us. If such an operation be decided on, it should be carried out as soon after the beginning of hostilities as

possible. The very power of modern armaments interferes with the rapid adoption of the means of defence. In the report of the Chief of the United States' Engineers for last year appears the following remarkable passage :—

"In the event of war with a maritime nation the cruisers and war-vessels of the enemy could run into our harbours, and without landing could either destroy the property along our shores, or else lay the people under contribution. The accurate, detailed charts of our harbours and channels, published by the U. S. Coast Survey, are accessible to all such nations, and are doubtless in their possession. If the enemy possesses depôts and arsenals in close proximity to our stores, the arrival of such armed vessels will follow in a few hours after a declaration of war. Thirty-six hours' steaming could bring vessels from Halifax; six hours', vessels from Havana; and ninety-six hours', vessels from Vancouver's Island, to important harbours of the United States. There might be very little time for preparation to meet the assaults of iron-plated ships, for they are plated with 6 to 15 inches of iron, and carry rifled guns from 9 to 14in. bore, all of which guns are more powerful than any gun we have in our service. With a fleet, or even a single vessel of this kind in one of our harbours, it would be of no avail to collect troops in the city or town threatened.

"Suppose we could concentrate 100,000 men in twenty-four hours at the point threatened, of what use would they be against the armoured ships?

* * * * * * *

"The parapets and traverses of earth and sand must be three, and even four, times as thick and massive, as they were built to resist the armaments of 15 years ago. Where the parapets of earth were ten feet in thickness, now they must be forty feet. Guns that were formerly dragged with ease by fifteen or twenty men, and placed in position over night, are now supplanted by armaments of such huge masses that special mechanical appliances are required to move them even slowly, and they cannot be lifted from their supports without the aid of hydraulic power. No matter how many men may be at our disposal the time required to place the modern armaments in position is vastly greater than for the guns of fifteen years ago; and before such works could be improvised the enemy in his ironclads will have accomplished all he desired, and have sailed or steamed for some other harbour to repeat the injuries of the first."*

This, coming from such a source, is fair proof of that of which we have had, in the history of the last quarter of a century, many other proofs, viz. :—the importance of making attacks as early in a war as practicable. This attack, called by the French *entrée de vive force*,† is the simplest of all those which a naval force would be called upon to make upon fortifications of any importance. We may examine the rules which the leader of such a force would have to observe in carrying out an operation of the kind.

* Report of Chief of Engineers in 1876. Washington, 1876. Part I., p. 4.

† *De la Guerre Maritime*, par. B. Grivel. Paris, 1869, p. 30.

First: as has been shown, it is highly desirable that the attack should be made soon after a declaration of war. Maritime fortresses are supposed to be always in a condition to withstand an attack. The Russian Government a few months ago, in a published scheme for the armament, under the new conditions of warfare, of the strong places of the Empire, laid it down as a rule that every fortress on the coast should have everything constantly in readiness to resist a hostile force. The fall of Soukhoum Kalé, unimportant or important as it may be as a defensive post, may show that this desirable readiness is not always attained in time. Therefore, an enterprising enemy has the chance of unpreparedness on the part of the defence on his side if he lose no time. Porter reported* that a heavy gun, which had been counted on much by the defenders of the Confederate forts on the Mississippi, had been removed for some improvement to be made in it, and had not been brought back in time to be used against the Federal fleet.

Second: the chief of the attacking force should make himself intimately acquainted with the nature of the place. "An *entrée de vive force*," says Capt. Grivel,† "cannot be attempted unless a laborious study of the charts, the works on shore, the movable defences, and the natural or artificial submarine obstacles justify the calculation of chances." The *Bulldog*, a vessel belonging to Her Majesty, was lost some years ago in the West Indies in consequence of grounding upon a shoal during an attack upon the batteries of some Haytian insurgents. The existence of this shoal could not have been distinctly known. In the preliminary operations which were followed by the Battle of Lissa, in 1876, Admiral Vacca's division of Persano's fleet steamed into the harbour of San Georgio, but was unable to efficiently support his friends on account of the difficulty of manœuvring from want of space inside the harbour.‡

Third: the amount of movable force—vessels, gunboats, torpedo-boats, &c.—at the disposal of the enemy should be known. To run successfully past forts and emerge from their fire in the shattered condition probable after such an engagement, to fall in with a fresh naval force beyond the batteries, would be to court failure, even though the hostile squadron might be inferior to the whole force of the assailant. After Farragut had passed the forts at the entrance to Mobile Bay his fleet encountered Buchanan's small squadron, and

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* Von Sheliha, *Coast Defence*, p. 22. See Porter's report to Admiral Farragut of proceedings of "bomb fleet."

† Grivel, p. 30.

‡ Hozier, *The Seven Weeks War*, vol. ii, p. 309.

but for the lucky shot which rendered the Confederate ironclad unmanageable, his losses would very likely have been far more serious than they were.

Fourth: if obstructions exist they should either be removed, or means sufficient to break through them be rapidly prepared. "No fleet can force a passage if kept under the fire of heavy batteries by properly constructed obstructions."* In the second attack on the Taku Forts in 1859, the "boom" placed by the Chinese across the channel kept some of our gunboats immediately in the line of fire of the guns. Sir James (then Captain) Hope cutting the chain at Obligado, in South America, in 1845, enabled the Anglo-French forces to get past the batteries on the river's bank.†

Fifth: the submarine defences, torpedoes, &c., should be first removed or destroyed, or the free passage through them be ascertained.‡ The loss of the Federal Monitor, Tecumseh, at Mobile, was, as I was informed by officers present in the engagement, in consequence of her being taken over a line of submarine mines, of the position of which Farragut was aware, and of which he had warned his captains.

Sixth: the enemy's works should, when possible, be exposed to a preliminary bombardment. Forts Jackson and St. Philip, on the Lower Mississippi, were compelled to submit to the fire of twenty mortar-vessels, commanded by Captain Porter, for a period of six days, before Admiral Farragut forced the passage. The effect of this bombardment may be estimated from Porter's statement that 1,500 shells were fired in twenty-four hours.§ Of these he claims that only 1 in 20 failed to explode.‖ And the enemy, he says, gave "the credit of reducing the fort to the bomb-fleet."¶ These mortar-vessels were stationed at distances varying from 2,850 yards to 3,680 yards, and in some cases were secured against return fire by being placed behind a point of land, and were further concealed from the view of the besieged by the intervention of "a thick wood, closely interwoven with pines," and their mast-heads being dressed with boughs to complete the concealment.

Seventh: arrangements should be made for towing off, or at least removing out of their consorts' way, such vessels as may be disabled by the enemy's fire or submarine defences. In a narrow passage a ship some distance from the sternmost vessels of the attacking column might, if sunk or rendered unmanageable, throw all the

* Von Scheliha, p. 124. † Yonge, *History of the Navy*, vol. ii, p. 561. ‡ Grivel, p. 30.
§ Von Scheliha, p. 59, ‖ Do. p. 93. ¶ Do. p. 22.

ships astern of her out of action, and split the force to which she belonged in two. As a general rule—if the protecting batteries are at all formidable—to run past them should not be attempted unless the channel be of sufficient width to allow of the following ships to clear themselves of such accidental obstacles. At Mobile Farragut's own column was able to pass clear of the sunken Tecumseh.

Eighth: a division of the force should be told off previous to the engagement to set about completing the work which was the real object of the passage as soon as the attacking vessels had got beyond the batteries. The remainder should prevent the enemy from repairing his defences, or obstructing the channel afresh, and thus cutting off the retreat of the successful assailants.

With respect to fortresses of the class of which Gibraltar has been named as the representative instance, it does not seem clear—even if they be far inferior in strength to that celebrated stronghold—what good purpose would be gained by a purely naval attack on them. They do not, as a rule, protect arsenals of importance, nor are they the most suitable refuges for ships that do not dare to keep the sea.

Since the completion of the modern works Cherbourg owes a not unimportant portion of its powers of defence to the outlying forts and batteries on the rock and mole, and, therefore, hardly belongs to the class in question. When taking part in a combined naval and military campaign, a fleet may be called upon to assist in the reduction of such a place. Aided by a besieging army on shore the work of the navy would be far simpler in such an attack than perhaps in any other. Hydrographical conditions would be such that no precautions, or but few, need be taken against submarine defences and obstructions. The true work of the naval force would be quite supplementary to that of the land force.

Batteries, comparatively secure against the besiegers' guns on shore, might be enfiladed by the fire of ships, which in general would be free to choose their own positions. Particular works possessing a power of annoying the besieging force might be left to the fleet to be silenced or destroyed. It is not likely that a garrison, unless very weak in numbers, would submit to a vigorous cannonade from ships without making some reply, so that in this way its attention might be distracted. The moral effect upon a body of defenders cooped up in the circumscribed limits of such a place consequent on finding themselves between two fires is likely to be considerable. The contest between the fortifications and the ships

would, in such case, resolve itself into an exchange of artillery fire. The ships would have all the advantages due to their mobility. They might be so placed as to offer no considerable mark to the hostile gunners, and at the same time to concentrate their fire on points determined on. It is not likely that in such an attack an Admiral would permit his ships to remain stationary, as was done at Sebastopol in 1854,* but, "keeping always in movement they should deliver their fire in succession."

The supreme naval effort might be deferred till the period of having recourse to the services of the assaulting columns was at hand. In the final bombardment of Fort Fisher Admiral Porter's fleet had fired, on three days, over 50,000 shells against the fort.† The work was captured by the assaulting parties of the land force after its parapets had been in effect destroyed by this furious fire. The attention of the garrison was directed to a body of seamen and marines which Porter was preparing to land from his ships. A less strenuous resistance was in consequence offered to the federal columns of assault which penetrated its works, and finally became masters of the place.

A naval attack upon a first-class maritime fortress, owing much of its strength to the hydrographical conditions of its site, is one of the most important operations of naval warfare. The prognostication of Sir Howard Douglas concerning the Crimean war probably indicates, with considerable accuracy, the course that a contest between naval powers will take in future.‡ He says "in the remarkable naval war in which we are now engaged there will, to all appearance, be no fights on the open sea, ship against ship, fleet against fleet, as of old; but attacks of fleets against fortresses and other land defences." The blockade and attack of the fortified places on the coast, and the sending out of cruisers to prey on an enemy's commerce, seem to be the duties in which in wars to come the navy will be most engaged. The mastery of the sea, or at least an unquestioned superiority of strength upon it, will be an inevitable condition of success for that fleet which essays to attack a great maritime fortress. The progress of science has rendered such attacks more and more difficult, and they will hereafter approach more nearly than heretofore to the operations of a great siege on land. Something more than merely to stand in and cannonade the opposing batteries for a certain number of hours—a proceeding with which the history of so

* Kinglake, vol. iii., p. 387. † Von Scheliha, p. 43.

‡ *Naval Gunnery*, p. 343.

many navies has made us acquainted—will be required now to reduce the stupendous works of recent construction.

First: it will be requisite that the navy which proposes to undertake such an attack shall have the command of the sea. Now that the use of steam power is universal, the mere fact of an enemy's fleet having been withdrawn to a distance from the place which it is intended to attack will not justify an Admiral in venturing to engage in so great an operation. To be caught by a hostile squadron entangled in the proceedings of a siege, with his ships more or less suffering from the resistance of the defenders, would lead more likely to destruction than defeat.

Second: the bearing of the attack on the general aim of the campaign or war should be distinctly understood. To risk ships and lives in attempting to reduce fortifications, the capture or destruction of which would tend little to influence the result of the war, should be carefully avoided. Against any such error of his own a commander is likely to be protected by the government of the country to which he belongs. Ministers, in possession of information from all quarters, and receiving reports from the leaders of both the land and sea forces wherever employed, are sure to lay down for the officers commanding the general plan of campaign which they should adopt.

Third: the season should be carefully selected. The dangers of delaying what would probably prove a protracted work, in the Baltic, for instance, hardly requires to be noted. But in all coasts certain seasons are less favourable to a prolonged stay than others. In the East, for example, the geographical position of many places renders them practically inaccessible during one monsoon, or half the year. Other places enjoy not only serene weather, but also a temperate climate for several months, whilst during the remainder of the year the seasons are both tempestuous and pestilential. On some great rivers the protecting fortresses can only be approached for a limited season. The depth of water, in general too shallow for powerfully armed ships, only increases sufficiently to give hopes of making a successful attack at the period of the melting of the snows near the upper waters.

Fourth: no attack upon a fortress of the first class must be undertaken until a sufficient force and a proper supply of stores have been collected. A mere fleet of heavy ironclads will not suffice to reduce an important place. The command must contain vessels of several descriptions; light draught gun-boats, torpedo boats to resist the

sorties of the garrison's floating defences, mortar-boats to bombard distant works. The quantity of stores requisite to a great undertaking of the kind will be prodigious. There must be provided full supplies of ammunition of all sorts, of counter-mines, of protective obstructions, and also of the articles required to make good defects in the ships themselves, and in their armament and machinery. The coast fortresses which the Federals attacked so frequently during the civil war were not by any means first-class fortresses, according to European ideas; yet, for their reduction, it was necessary to maintain a stupendous fire. In the second siege of Sumter "the batteries expended 5,009 shells." One captain (Stevens) reported "that 455 shells were fired in seven days." From the shore and the ships "2,864 shot and shell had been fired against battery 'Wagner' during forty-two hours." At Fort Fisher "during the last bombardment, on January the 13th, 14th, and 15th, there were fired over 50,000 shells against the fort."* If, remembering these figures, we reflect that the supply of ammunition to Her Majesty's ships is but 85 projectiles per gun on the broadside, and in no case more than 170 per gun, we shall see that the amount of reserve stores, required in such an undertaking as that we are considering, would be vast.

Fifth: some conveniently placed and easily defended harbour in the neighbourhood of the fortress to be attacked must be seized by the attacking fleet before beginning. It is obvious that the fleet itself would be numerous. At Sweaborg, in 1855, the allies had six line-of-battle ships, besides frigates and steamers, twenty-one English and French mortar-boats, and twenty gun-boats.† At the passage of Forts Jackson and St. Phillip, Farragut had thirty steamers, besides twenty-one mortar-boats.‡ In December, 1864, Rear Admiral Porter opened on Fort Fisher with the batteries of not less than thirty-three vessels, besides eighteen in reserve.§ In the following January, he re-opened fire from forty-four ships. The supply fleet would also be very large, and it would be found essential that some secure anchorage should be at hand for many vessels, both to ensure their safety, and to prevent the movements of the besieging squadrons being hampered.

Sixth: the attack should have always some definite object, and this object should not be lost sight of. For instance, in the case of such a fortress as Cronstadt, as it appears from the latest map in

* Von Scheliha, pp. 9, 16, 33, 36.

† Yonge, vol. ii. p. 660. ‡ Fletcher, vol. i. p. 402. § Von Scheliha, pp. 33, 35.

my possession,* an assailant might propose to himself to reduce the various forts until he could reach a position from which to destroy, by shell-fire at high angles, the arsenal buildings and the ships in the port. With this object in view, the attack would naturally be made from the north of the island. Indeed this, as we have been told by Sir Howard Douglas, would be a law governing such operations. Outlying works should be first reduced, and the operations should proceed so as to compass the destruction, or silencing of the various forts and batteries which support each other by their position and the direction of their fire. "Isolated points of defence mutually protecting each should be attacked in detail, and successively reduced, after which the fleet may arrive at and attack the main position."†

Seventh: the fleet should be split up into divisions, to each of which some particular duty would be assigned. A flotilla of mortar-boats would be told off to bombard those defences which could be best reached by, and would be likely to suffer most from, curved fire. Barbette batteries and hastily constructed earthworks would be especially liable to damage from such attack. Divisions of light-draught gun-boats armed with heavy guns should be distributed about, so as to converge their fire upon particular points. The large ironclads should be placed where the water would be deep enough to float them without risk, where there would be room for collections of them to manœuvre, and where they could bring a heavy direct fire upon defences impervious to other attack.

Eighth: means of protecting the attacking squadrons should be devised. Floating obstructions formed of boats and chains might be arranged as a screen against torpedo-boats, behind which screen ships might move and deliver their fire without much danger of counter-attack. The swift torpedo-boats of the assailants should be kept in readiness on the flanks, as it were, of the bombarding ships, to repel any such counter-attacks made by the besieged.

Ninth: a carefully devised plan of clearing obstructions should be prepared. As Captain Grivel‡ observes, "If the natural difficulties vary according to the configuration of the place, we must not forget how far the genius of the defence can complicate the task of the assailant." The dangers of the submarine mines have, in some

* Courteously supplied me with other valuable information by Mr. Wild of Charing Cross.

† *Naval Gunnery*, p. 351.

‡ *De la Guerre Maritime*, p. 31.

respect, been neutralized by the power of the marine counter-mine, and an extensive supply of these objects should be at hand.

Tenth: careful and accurate surveys should be made of the place, of the surrounding waters, and of the works. However perfect and minutely detailed may be the plans and charts which the attacking commander may be placed in possession of, he should not rest satisfied with them unless they be of very recent date, or executed by officers under his command. In many of our own wars, whatever success has attended the naval operations has in great part been owing to the intrepidity and skill of our surveying officers; to prove this I need only recall the names of Collinson in China, Spratt in the Black Sea, and Sulivan in the Baltic.

It is now proper to consider the relative chances of success of the attack and of the defence, due regard being had to the conditions of modern warfare. It must be admitted that the balance of authority is decidedly against the feasibility of successful attack on a fortress of any strength by a fleet of ships. It is true that some men of unexampled experience of that style of warfare have raised their voice on the other side; but they are a minority, an important and influential minority it is true, but still only a minority after all. Sir Howard Douglas, whose name British Naval Officers should always regard with gratitude and veneration, has said that "the attack of fortresses and powerful land batteries with a naval force only, must ever be a hazardous and desperate undertaking."* It should be remembered that the distinguished author wrote this at a time when considerable attention had been paid to the work of strengthening coast defences, and before the occurrence of the great revolution in naval architecture and the armament of ships of war, which we have seen within the last fourteen or fifteen years. Rear Admiral Porter, of the United States' Navy, than whom no man had more experience of engagements between ships and land fortifications, held a very different opinion, and thought—or indeed was convinced—that provided the channels were clear of obstruction, a naval force, not greatly superior in gun power, had more than a fair chance of succeeding in conflicts of the sort. But with respect to his views also, it is only just to recall that he wrote fresh from the experience of several combats between ships, armed and protected on the very newest principles of the time, and forts constructed or planned thirty or forty years before, and intended to

* *Naval Gunnery*, p. 347.

withstand the attacks of vessels which, when the Admiral himself came to command fleets, had become quite antiquated and obsolete. Many of the most powerful coast fortresses, even of the present day, still have much of their works built of masonry; and Colonel Collinson, R.E., has said "no masonry, except of very massive character, can be expected to stand for many hours the effect of such projectiles as those of the 300-pr. or even the 150-pr. Armstrong gun."* Now unless the coast batteries and forts of the world have undergone an almost complete re-construction since the introduction of the newer heavy naval guns, we may apply to them, in view of the greatly increased power of artillery, the same argument *à fortiori*.

Sir Howard Douglas has also said that "however successful a naval attack of a fortress or arsenal may be, the work of destruction can never be effectually accomplished by ships. The sea defences may be silenced, guns dismounted, parapets ruined, magazines blown up by mortar shells, and habitations devastated by the cruel process of bombardment; but no substantial demolition of the defences, or material destruction of the public works and property can be effected unless the damages inflicted by the attacks of ships be followed up and completed by having actual possession of the captured place for a sufficient time to ruin it entirely. No naval operation, however skilfully planned and gallantly executed, can alone reap the fruits of its victory."† Col. Soady, R.A., in his work on the *Lessons of War*,‡ quotes a somewhat similar opinion of Sir William Jervois; and, in another passage§ to the same effect, says: "A fort is able to inflict far greater damage upon its assailant than the latter can inflict upon it; whilst it will hit the assailant nearly every time, the chance of the assailant hitting it more than once in the same spot are small. Further, one shot may send a ship to the bottom, whilst the fire from a ship during action is more or less inaccurate." Now it is hardly too much to say that these statements have been directly traversed by the actual experience of the war in America. Von Scheliha, writing in the full light of that experience, has it that "the sinking of a vessel by artillery fire is usually the result of a fortunate chance which has directed the shot to some vital spot." As a matter of fact powerful forts were completely silenced by the fire of guns; and though not indeed taken by assault, were so far made useless to the defence that any ship might have passed by them with impunity. After the second bombardment of Fort Sumter only a

* *Professional Papers*, R.E., vol. xiv., p. 69, 1865.
† *Naval Gunnery*, p. 353. ‡ *Lessons of War*, p. 163. § *Ibid*, p. 157.

few serviceable field guns remained, and even these had to be placed under shelter by day.

Again we have Sir Howard Douglas' own authority for believing that the configuration of many points of a coast which have to be fortified, and the low elevation of such points, conduce to the success of a naval attack. "Batteries placed nearly on a level with the water are far more subject to the fire of ships, and are much less formidable to them than batteries elevated somewhat above the surface of the sea. * * * Should any guns be mounted *en barbette** they would inevitably be dismounted." So too, "An enemy will always have the advantage of being able to concentrate against any number of guns ashore a larger number of guns on his ships; may commence an engagement or break it off at his own convenience; may choose his own ranges and positions; * * * the fire of 100 guns or more may be concentrated at the same time."† Thus the naval force has on its side the advantage of the artillery law deduced from the experience of the latest wars, viz.:— The most effective use of artillery power lies in the distribution of the guns and the concentration of their fire.

It is true that a naval force acting alone can hardly hope to take possession of works which it has battered to silence by the superiority of its fire. Nor in a siege on land does it lie with the engineers who trace the batteries, or the gunners who work the guns, to seize the place when its fortifications have been breached. That is the duty of the columns of assault, of the "forlorn hope," drawn from the ranks of the infantry corps of the besieging army. But what a naval force may hope to do, and what it has done ere now, is to reduce the batteries to such impuissance that it can disregard them, and then stand in and destroy the ships or works which the same batteries were erected to protect.

In considering what lies before a fleet of ships to which it has been entrusted to reduce a great fortress, the first thing that occurs to us is how to remove the obstructions which the defenders are sure to have constructed. The ruinous result of using such permanent obstructions as sunken ships are now so well known (for they injure a harbour far more lastingly than anything an enemy is likely to do) that we may believe they will be rarely made use of in future. The processes of nature will not unfrequently come to the assailant's aid in this particular, and it has been noted that sudden floods and violent storms have shattered defensive obstructions, and even displaced

* *Naval Gunnery*, pp. 335-6. † *Von Scheliha*, pp. 43-4-5.

and neutralized the effect of submarine torpedoes. Floating obstructions must be very strong to withstand the shock of a steam ram of not very large size, and—providing the general depth of water be sufficient—such a vessel may probably be advantageously driven against it. Should the obstruction be placed so as to be under the heavy fire of the guns of the defence—to which it would not be advisable to expose a ship till the obstacle was removed—the batteries must first be subjected to a heavy bombardment from as near as the obstructions will permit; or explosives, intended to burst on contact, must be sent in with the tide, or be deposited against it by electrically-steered steam-boats.

Submarine mines undoubtedly present a formidable obstacle to the attack. Still, there is good reason to believe—from our recent experiments—that they too can be removed or destroyed. I may quote from a very interesting account of some experiments which were carried out at Portsmouth only a short time ago. They were "intended to illustrate the method of entering an enemy's harbour where torpedoes are known to be deposited. This can now be as certainly effected by what are known as countermines as, in the case of land warfare, a fortress can be gradually approached by sappings and trenches. These countermines are conducted in various ways, but they have all the same purpose in view, which is to destroy the enemy's mines by exploding others in their midst. It is believed that the explosion of 500 lbs. of guncotton below water will clear an area having a radius of 120 yards. The method generally adopted is to take advantage of the tide, the current, or the wind, and to drift the countermine into the required position. When the charge is too heavy to float in consequence of its own buoyancy, the necessary floatation is secured by attaching it to some foreign object in the shape of a cask or buoy. * * * * A net containing 15 lbs. of wet guncotton was discharged; and, in order to show that there need be no limit to the number of countermines in the same connexion, twelve small charges of guncotton, representing as many countermines of 500 lbs. each, were simultaneously discharged, thus demonstrating the possibility of extending these operations over wide areas of disturbance." *

Sweeping, "creeping," dredging, diving to cut electric wires are all methods which have been tried with success. With regard to the distance from the defenders' works at which these mines are likely to be encountered, as yet no very safe guide can be laid down. Some officers are of opinion that it will not be advisable to lay down such defences much beyond the effective fire of the guns and projectiles that would probably be used against exposed boats. My own belief is that we should be ready to meet with them very much farther out. But this is a question more for the engineers of the defence than for

* *Times*, June 6th, 1877.

those of the attack. In any case an assailant will have to proceed with caution, and to clear carefully every step of the way, even though he begin his operations at a very great distance from the works.

The attacking fleet must be in a condition to resist the offensive sorties of the garrison. These will either take the form of squadrons issuing from behind the fortifications to enter into a regular engagement, or isolated attacks of torpedo-boats, or of Whitehead torpedoes. Unless the attack be strong enough to keep a division of ships constantly in readiness to engage such squadron as the enemy may have to send out, without interrupting the fire upon the batteries, it would be better not to undertake to reduce the place at all. The heavy ships and gunboats charged to maintain a fire upon the fortress may be protected by obstructions—easily removed when an advance is requisite—which will effectually prevent the approach of any torpedo-boat yet known. If the firing divisions are manœuvring at certain distances from the forts, they may move to and fro or round and round, as may be desired, behind a screen of boats and chains which it will be almost impossible to break through, and may be further protected by a few swift steamboats, which can run down or engage the craft sent out by the defenders.

Torpedo attacks are likely to be made under cover of the darkness. The screen of chains and boats, and the swift steamers just spoken of can be supplemented by the various methods of lighting up approaches which have recently been brought into notice. I will quote again from a late account of some of these methods.

"When it is established that no gun-torpedo can be effectively launched to insure impact within moderate short range, and that no torpedo launch can act with effect except it absolutely approaches the vessel within striking distance, neither can any torpedo be affixed or placed near a ship except the forlorn hope actually approach the vessel; the most valuable means of defence, and the one to which special attention should be directed is that of illumination. Light of sufficient power to disclose any object attempting to enter a cordon of illumination round a ship, the ship itself remaining in darkness, is at once the simplest and most effective precaution that can be devised against night attack. * * * * * * Within the last few weeks a very important advance has been made towards solving this problem of illumination at sea by an adaptation of what is known as Holmes' distress signal, in the form of a shot for illuminating purposes, to be fired from mortars at ranges varying from 500 to 2,500 yards. These signals possess the remarkable property of emitting a very powerful white light the moment they come in contact with the water, and when once ignited are absolutely inextinguishable by either wind or water, and burn with a persistency that is almost incredible, 30 or 40 minutes being an average duration. * * * * * Some half dozen of these shots, fired from an ironclad or gunboat, would effectually surround her

with an impassable cordon of light, while the vessel herself would remain in darkness."*

In addition to this illuminating shell another has been invented by a M. Silas, of Vienna, out of which, when fired, two streams of illuminating matter are poured upon the sea. There can be no doubt that—when the alarm has been given by the look-out boats stationed in advance—to be able to illuminate the path of the enemy's approach will add greatly to the facility with which ships lying off an enemy's fortress can be protected against night torpedo attack.

The main attack upon the batteries will, of course, be by artillery fire. The use of mortars will probably be largely had recourse to. Recent experiments with curved and high-angle fire in Russia have shown how formidable such fire is to ships, no matter how thick be the armour on their sides, and also to fortresses. At Nicolaiev towards the end of last year, after two days' practice with mortars at targets representing circular ships, or *Popoffkas*, and large iron-clads, it was found that on one day 33 per cent. of the shells fired, and on the other day 22 per cent., fell on the space representing the deck.† At Cronstadt 22·2 per cent. of the shells fired from twelve 6-inch mortars at a moving object, a barge smaller than an ordinary gun-vessel, struck the target.‡ This will show some of the dangers from vertical fire which ships attacking must expect to incur. As Colonel Inglis, R.E., has said, "The general conclusion to be drawn is that a deck plated with two thicknesses of $\frac{3}{4}$-inch iron is not proof against short-range 9-inch shell."§ The land defences, at the same time, are extremely open to the dangers of such vertical or mortar fire. We have seen what Porter's "bomb fleet," did on the Mississippi. To quote a former authority, "A bomb ship may, without much exposure, do great damage to an extensive fortress or arsenal; which, being a large object, ought to be struck at every discharge at upwards of 4000 yards, whilst the bomb ship is a mere speck on the sea at that distance."‖

With respect to the method of delivering the direct fire against the defences of the place, it may be laid down that, unless the mortar vessels and vessels firing at high angles can be protected by some intervening point of land of sufficient elevation, all engaged should do so whilst in motion. This has been known as an unquestioned advantage of the use of steam locomotive power; and at Sweaborg

* *Times*, June 5th, 1877. † *United Service Magazine*, Dec. 1876, pp. 475-6.

‡ *Revue d'Artillerie*, vol. ix., p. 489.

§ *Professional Papers*, R.E., vol. xx., p. 47. ‖ *Naval Gunnery*, p. 355.

and Odessa ships moved in circles whilst engaging the batteries, and would have done so, but for the change in the plan at the last moment, at Sebastopol. The circle does not seem so well adapted to ensure the protection of the vessel and the rapidity of fire as the ellipse. If the circle be of sufficiently large diameter to withdraw the ships, on their outside passage, out of range of the guns of the defence, the traversing of its circumference will be necessarily slow. If the diameter be reduced the exposure will be considerably increased. In attacking such a fort as that marked Alexander on Mr. Wyld's map of Cronstadt, the position selected would naturally be that on the capital of the Northern bastion. An ellipse described at a distance of 3,500 or 4,000 yards from the bastion might have a major axis of considerable dimensions at right angles to the capital; and the curve presented to the fort would be flat enough to allow of more than one discharge of the guns in passing. On getting nearer to the defences the major axis of the ellipse should be in the other direction, that is in the line of the capital, so that the ships on delivering their fire might go to a considerable distance outside the fighting range. Both figures would be contained very nearly, if not quite, within the limits of the "sector of impunity," or horizontal *dead angle*. The speed at which these curves should be described by the ships would not fall short of six knots. Several tables of the probable number of times a moving ship could be hit by the guns of a battery have been constructed, *e.g.* by Captain Grivel in his *Guerre Maritime*;* but it will suffice here if I mention that it has been found by experiment in this country that, "Crossing the range of a 12-ton gun mounted in a casemate where the traversing angle is 70,° at a distance of 1000 yards, a vessel moving at a speed of 10 miles an hour may be fired at six times. The 22-ton gun would have fired at her three times."† Occasions may occur when it is possible to select a position from which a ship can fire against a battery without having to move about. I can remember one such case in my own experience during the Russian war, when a ship, which her captain had run in as close as the depth of water would permit, was able to take up a position so far to the left of the embrasures of an earthwork specially constructed as a defence against ships, that the guns could hardly be trained to reach her. The great advantage on the side of the ships will be their power of distribution and of concentrating their fire, in addition to the small objects presented by many gun-boats, which will carry the heaviest, or almost the heaviest guns.

* p. 37. † *Report of Committee on Fortifications*, app. 3, p. 6.

Looking back and reviewing the whole question, it is not easy to avoid the conviction that to attack a great fortress we should require a vast force. Heavy ironclads would have to be numbered by dozens, and gun-boats and mortar-boats by fifties. We attempted little, or failed in what we did attempt, in the war with Russia, because, as we can now—by the light of present experience—see, our means were ridiculously inadequate to the end we proposed to ourselves. It will be the same again if we do not recognise the fact that our preparations should be such as to give us some promise of successful performance.

In conclusion I may say that I am very apprehensive of having said to you little that was worth hearing. I have possibly recalled some facts that had once been known, but have been now forgotten. I must plead in extenuation of any failure to interest or enlighten, what I said in my prefatory remarks; and I may add that this paper has been composed under somewhat serious difficulties. I returned to England only a few weeks since with health shattered by a rather long service abroad; and since I have been at home, since indeed I began the composition of this paper, I have had an attack of illness which rendered any work all but impossible. Added to all which there have been the distracting influences which act upon one who has recently returned to the society of friends whom he has long been absent from. I cannot regret, however, that I accepted the invitation extended to me on behalf of your Institution. It has turned my attention to a branch of warfare too much neglected of late; and it has enabled me to realise, in some measure, the immense debt of gratitude which England owes for her security to the officers of her Royal Engineers.

CYPRIAN BRIDGE,
COMMANDER, R.N.

PAPER XVII.

ON THE UTILIZATION

OF

CARRIER PIGEONS

FOR MILITARY PURPOSES.

By W. B. Tegetmeier, Esq., F.Z.S.

A Lecture delivered at the Royal Engineer Institute, Chatham.

It may appear bold on my part, as a civilian, to address an audience chiefly composed of military men, on a subject that apparently has but a slight bearing on military science, but I am emboldened by the recollection of a great authority, one who was well versed in a variety of subjects, who stated that he owed the vast fund of information he possessed to a habit of never neglecting an opportunity of acquiring knowledge from any individual, however humble. He saw that every man possessed in his own speciality something from which he could learn; and, possibly, I may have, from the special knowledge which I possess on this subject, something to say that may be interesting to you, and that may be found to be not without its interest and value, looked at from a purely military point of view.

The application of the homing pigeon to military purposes is one that I think I had perhaps better introduce by a few remarks on the history of the bird, and on the origin of the faculty which it possesses.

The wild original of our domesticated pigeon is the blue rock dove, the *Columba livia* of naturalists; in its wild state it inhabits rocky places on the sea shore, and seeks its food from a wide expanse of country, sometimes at a distance of many miles. In order to return to its nest and rear its young, which are fed by the parents during a period of some weeks, the birds must possess the habit or

faculty of observation, and be able to retrace their flight under all conditions of atmospheric variation.

This pigeon is one of the few birds that possess the instinct of domesticity. Many persons imagine that almost all animals can be domesticated. This is an idea that is repudiated by naturalists, who know that only about 40 of the whole of the animal creation, consisting of several hundred thousand species, have been reduced to a domestic state by man; it is doubtful, indeed, whether there are many more that could be domesticated. For example, it is impossible to domesticate pheasants. They may be reared, generation after generation, in aviaries, but as soon as they acquire the power of flight they go off to the woods, and are no longer domesticated animals. On the other hand, the blue rock pigeon taken from the nest and placed in a dove cot at once becomes attached to the spot, and remains a domesticated animal—not necessarily a tame one, because it may be as wild as possible, and yet, at the same time, domesticated, or attached to its own domain or home. The possession then of this faculty of domesticity, and also that of returning to its home, unite to give the peculiar value of this pigeon as a homing bird.

Like all domesticated animals pigeons are subject to great variation; in some of the varieties this faculty has been cultivated to a very high degree, in others it has not. In England we apply the term carrier pigeon to a pigeon that will not carry at all. What is commonly called a carrier is a fancy pigeon, which is valued not on account of its power of flight, which it possesses in a very limited degree, but for the enormous amount of corrugated flesh that exists about its beak and its eye. The birds that are really trained for flying are birds that have no fancy characteristics. They are valued solely on account of their great power of flight, a power that is indicated by the enormous breadth of wing feathers, the extent to which they overlap, and for their powerful wings, with vast muscles to move them; all such characteristics as colour are put on one side, and the young birds are reared from those who have performed the longest distances in the least possible space of time.

To show you how strong this faculty of homing is in a good bird I may mention that one not only flew to Brussels in a race, starting with 440 competitors, but having been returned to London for exhibition, and being let accidentally out, she went back to Brussels a second time, unaccompanied by any other pigeon.

The Belgians have cultivated this breed of homing pigeons to a much greater extent than any other people. In Belgium pigeon racing is really the national pastime. Thousands of pounds are devoted every year for the training and racing of pigeons. His Majesty the King of the Belgians gives the chief prize, and the Heir to the throne gives the second prize in the great national race of the year, which is usually from some town in the south of France. There are hundreds of societies, and tens of thousands of amateurs, interested in pigeon racing, all of them keeping this variety of pigeon, and racing it various distances, from fifty to four or five hundred miles. Sometimes they race from as far as St. Sebastian, but usually their long races take place from some town in the south-west of France.

Having called your attention to what is being done in Belgium, I would mention a few of the uses that have been made of these *voyageur* pigeons in England.

Before the introduction of the electric telegraph pigeons were very largely used by the stock brokers. The news of the battle of Waterloo is said to have been transmitted by pigeon express, and received by the Rothschilds before it reached the ears of the British Government. Pigeons have also been largely used for sporting purposes, conveying messages from the different race courses to London, announcing the names of the winning horses. Not only in England were they used in this way, but likewise abroad. One example I may mention, because it bears somewhat upon our subject. The editor of the *Colombo Observer*, in Ceylon, had a number of homing pigeons which used to bring intelligence from Point de Galle to the capital, Colombo, a distance of from 70 to 80 miles. Ships going out to India and China touch at Point de Galle, and then go on their course, and before the establishment of the electric telegraph the information that the ships brought was conveyed from Galle to Colombo by pigeons. When the news of the fall of Sebastopol arrived, the Governor caused a salute to be fired in honour of the victory on the faith of intelligence brought from the Point de Galle by pigeons. On the establishment of the electric telegraph, Dr. Ferguson, the editor, gave up his birds. But he afterwards found that the delay in the transmission of messages by the electric telegraph, combined with the not infrequent inaccuracy of such messages, were so serious that he applied to me for a dozen pigeons in order that he might re-organize his pigeon telegraph, as being much

quicker and more reliable than the electric telegraph as worked by the natives.

In one of the races which took place from the Crystal Palace to Brussels it was agreed that on the liberation of the birds, at twelve o'clock in the day, I was immediately to despatch a telegram to the secretary of the society in Brussels. I accordingly did so, announcing the flight of the pigeons, the nature of the weather, and the direction of the wind, which would influence the rate of flight. The first pigeon arrived at Brussels at 20 minutes past five, the weather not having been very favourable. The telegram announcing the departure of the birds arrived there at half-past five, so that the winning pigeon on that occasion beat the telegraphic service by ten minutes. I give this as an interesting example of the speed at which they fly; of course I do not say that the electic telegraph will not equal the pigeon-despatch provided special arrangements are made, but, practically, in a great many instances the pigeons will beat the telegraph, and they did so on this occasion.

With respect to the speed at which pigeons fly, I may mention to you that for short distances, with good weather and a favourable wind, it will approach 60 miles an hour. Pigeons have been known to fly 45 miles an hour for eight hours in succession; of course the longer the distance the slower the rate.

The most interesting service that has ever been performed by these homing pigeons, and a service which bears most strongly upon their use for military purposes, was the employment that they were put to during the siege of Paris; when that city was surrounded by the German forces, and all ordinary means of intercourse from without were cut off, communication could easily be made from the inside of Paris to the outside by means of balloons, but the difficulty was to get messages conveyed from the outside to the inside. It so happened that there were two Colombophile Societies in Paris at that time, and they had about 400 birds belonging to the members, who immediately placed their pigeons at the disposal of the Government, and every balloon that went out, took with it a certain number of *voyageur* pigeons. They were not particularly good birds, as the members of the societies had not practised their birds to anything like the distance flown by the Belgian amateurs; but still they were birds capable of flying back to Paris, forty or sixty, or perhaps a hundred miles. The experiment was tried rather roughly, but still it succeeded; for the pigeons that went out brought back despatches of considerable length, printed in the first instance on small pieces of

paper. I have here one of those earliest despatches in a cipher consisting of numbers; it is signed by M. Tachard, who at that time was the French ambassador in Brussels. These despatches were in the first instance sent to Tours, one of the nearest towns to Paris which was not invested by the German Army, and the pigeons brought out of Paris by the balloons, were liberated in the same town, and flew into Paris with the papers attached. In addition to the government cipher a number of letters were set up in type, and both M. Tachard's despatch and the letters were micro-photographed, and thus, in this small compass, were attached to the pigeons. Shortly after, M. Dagron, a celebrated photographer, placed his services at the disposal of the Government, and the pigeon post was organized. I have here the bill of the Government regulations, issued from the General Post Office, London, dated Nov. 16th, 1870. The letters for despatch into Paris, by pigeons, were to be sent open, and were at once forwarded by our postal authorities, to Tours, where they were immediately set up in type, and micro-photographed on thin films of collodion; of these films one, containing upwards of 3,000 different communications, each limited to twenty words, weighs only two grains. Thus prepared these films were rolled up tightly, placed in a very small quill, and tied to the feathers in the tail of the pigeon, which was then let off. Tours being only 40 miles from Paris, the flight was a mere bagatelle to a good bird. If the weather had been fine, and the pigeons had been good, all of them would have got back to Paris; but some did not return, so duplicates were sent, all consecutively numbered, until the French postal authorities at Tours received an intimation by balloon, that they had been received.

So exceedingly light were these films, that one pigeon could have carried the whole of the communications that went into Paris during the siege, amounting to 300,000 letters.

During the siege of Paris, 64 balloons left the city, conveying in addition to the æronauts, 363 pigeons, and 3,000,000 letters. Of the number of pigeons that were taken out, only 57 returned. The microscopic despatches taken in by these 57 pigeons would, if printed, have formed a bulky octavo volume.

I would now call your attention to the work that has been done in England with pigeons, since the siege of Paris. Perhaps the most important application of the homing power of these birds, is that with which I have been entrusted by the Elder Brethren of the Trinity House. In consequence of the wreck of the "Deutsch-

land," off Harwich, some time ago, and the great loss of life that took place there, the Elder Brethren thought it desirable to attempt to make communication from the light-ships to the shore. Telegraphic communication with the light-ships is, I believe, impossible. The light-ships are moored by long chain cables, and swing with the tide, which arrangement is incompatible with the integrity of electric communication. Rockets are only available at night, and in clear weather. Flags are only to be seen by day, and some of these light-ships are out of sight of land, as is that on the Kentish Knock, where the "Deutschland" was wrecked. It was thought that pigeons might be made available, and in consequence I am conducting an experiment of this nature. The place that has been selected for the experiment is Harwich. In this town is an old unused light-house, now no longer required. This has been placed at my disposal, and I have now there a good stock of young pigeons, the object being to send some half-dozen or more to each of the light-ships, and then, when any message is required to be communicated to the shore, certain letters taken from the maritime code of signals will be stamped on the wing of the pigeon; for instance, "H B" may mean "Send a lifeboat," and so forth. In no case will more than three letters be required. We think it will be better to allow the sailors to stamp certain letters on the wings of the pigeons, and then liberate them, than to attempt to instruct them to tie messages round the legs of the birds, for this is rather a delicate matter; whereas they will have no difficulty in using a stamp containing certain type letters. When the bird is liberated, it will return to its home in Harwich, be caught, the message read and acted upon.

These light-ship birds will convey messages of wrecks and so forth to the light-houses on shore, so that the life-boat might be sent to either of the light-ships as required. Had there been on board the Kentish Knock light-ship, at the time of the wreck of the "Deutschland," half-a-dozen pigeons, they could have been liberated, they would have gone to Harwich with the message, the life-boat could have gone out immediately, and no doubt the majority of those lives that were lost would have been saved; at least, that is the theory on which we are working.

Another use which is made of these birds in England is for police purposes. I find that the Superintendent of the County Police at Ipswich, which is near to Harwich, has a staff of these birds. The police usually drive out into the country in small light carts, and take with them some trained pigeons. Supposing a

constable in a part of the country far removed from any electric telegraph, wants assistance, or that he requires to make any communication to the head office, he writes his message on a piece of paper, ties it with a piece of thread round the leg of the pigeon, liberates the bird, and in the course of a few minutes or half-an-hour (it must be a large county that a pigeon could not fly over in half-an-hour) the intelligence is at the head-office, and the assistance can be sent, or the information be used.

With regard to the application of these capacities of the bird to military purposes, it is simply carrying out the same idea endeavoured to be carried out at the present time at the light-ship at Harwich. This use has already been achieved by the Germans. Seeing the utility of the pigeons to the besieged Parisians, they have organized a pigeon service at their own fortresses, and I believe there is not now an important fortress in Germany, and certainly none in France, that has not its flight of homing pigeons. Old birds are procured, and shut up in aviaries to breed. When they have bred, the young ones can be flown, which would be impossible with the parents. If you take this bird for instance, which has flown twice from London to Brussels, and shut it up two or three years in a large aviary where there is good room to fly and maintain its strength, the bird would rear its young, and go on living just as happily as though flying. But if let out, it would rise in the air, possibly describe two or three large circles, perhaps not even one, and would go away in search of Brussels. Nay, if you were to take that bird, and cut off half its feathers, and then allow its power of flight to be gradually restored, as it acquired new feathers by moulting, it would get to the top of the house; then as it produced new feathers, it would fly round with the other pigeons, and as soon as it had procured its full complement of feathers, your place would probably know it no more. The bird might not have strength to get across the sea to Brussels, but it would make the attempt. It is evidently impossible, therefore, to buy a number of these pigeons, and to set up a flock for immediate use. To do this a commencement must be made with young pigeons that have not flown, or a number of birds must be allowed to breed in a large aviary, and the young ones reared, liberated, and trained.

In the case of a fortress, the young birds would have been trained to fly back to their home first from short distances, then two or three miles, then five or six miles, and so on, until at last you had them returning from distances of 30, 40, 50 or even 60 miles, and then up to

100 miles. Now suppose the fortress besieged, then before its complete investiture you would send out 30 or 40 pigeons; or, even after its complete investiture, you could organize and send out some pigeons by a small balloon, to bring back messages when liberated.

The value of homing pigeons, in such places as Jersey or Guernsey, in case of a war with any European power that had the means of cutting off telegraphic communication, would be inestimable.

Let us suppose that we expected to see an enemy's fleet in the channel. Of course swift steaming vessels would be sent out to watch this fleet, and to bring the intelligence back to England; but to get the intelligence to England, it would require the vessels to leave off watching the fleet, and to come back at an expense of several hours or days sailing, to Portsmouth or Southampton, to deliver that intelligence. But supposing on the other hand that these vessels sent out to watch the fleet, had on board a basket of pigeons duly trained, intelligence could be sent off from hour to hour, and from day to day, the frigates stopping all the while to watch the enemy.

When Captain Webb swam across the Channel, an illustration was afforded of the manner in which these homing birds can be used. The steamboat that went out to watch him took a number of *voyageur* pigeons from the pigeon fanciers at Folkestone; and hour by hour as Captain Webb went on, his rate of progress was brought back to England by these birds.

It appears to me that if the Germans have thought it necessary to establish *voyageur* pigeons in their fortresses, surely it must be also desirable for the English to employ them. I imagine that there must be many localities, such as Jersey or Guernsey, and other places, to which, or from which, it would be exceedingly desirable to be able to convey messages supposing they were invested. Perhaps they would be less available to us in England than they would be to the Germans, or the French, or the continental powers generally, but surely there must be, or may be, many situations where their use would be of great importance. Of course in our own country it is obvious that their greatest value would be for those vessels that go out to watch an enemy's fleet, but there may be, I should say, many other conditions under which they could be very usefully employed.

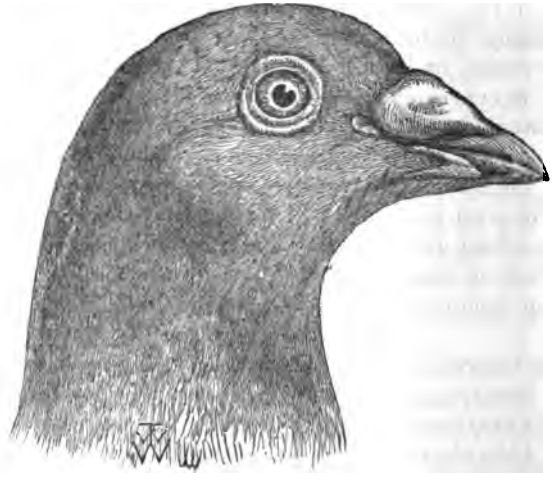
I believe theories with regard to their utility have been started that are perfectly incompatible with the nature of the bird's homing faculty. It has been said that pigeon houses could be taken with armies, and the birds on being liberated could fly back with messages

to their movable homes. This is all nonsense. It would be quite impracticable to organize sets of pigeons and pigeon houses after this fashion.

The only mode in which pigeons can be used is in conveying messages back to the places where they have been reared. It has been objected by some that the birds will be of no use in a fog. The same objection might be made to the use of signals, or flags at night. We have in these cases to avail ourselves of all the means which are possible, and under certain circumstances a pigeon carrying long despatches and long messages is really more valuable than any other mode of communication.

I have endeavoured to show you the circumstances under which *voyageur* pigeons can be used, and the circumstances under which alone they are applicable; and I want particularly to remove the impression that the pigeon is capable of being used under all circumstances. I think that there may be conditions under which they may be used with advantage in connection with military operations, and with this feeling I have endeavoured to place them before you, and I thank you for your attention to what I have had to say.

Head of Homing Pigeon.



The engraving shows the true type of head of the *voyageur* or homing pigeon, as distinguished from the long faced English fancy breed known as the Carrier. The bird whose portrait is engraved has flown several times from Brussels to London.

W. B. TEGETMEIER.

A question was asked as to the percentage of birds which was lost from being shot, or from being attacked by birds of prey?

Mr. Tegetmeier replied, that the pigeons flew so high as to be practically out of the range of fowling pieces, and that in England the loss from birds of prey was very small. There were very few places where hawks were common, and the preservation of game in this country was so much attended to that there was very little loss from birds of prey. In Belgium prizes were given for the destruction of hawks.

Colonel Hassard in expressing the thanks of the audience to Mr. Tegetmeier, wished to supplement it by a few remarks: Commander Wharton, of H.M.S. "Fawn," lately at Sheerness, thought that pigeons might be used in surveying service, in which that ship is employed, and had taken some with him for that purpose; baskets had been specially made to go under the thwarts of the boat, and pigeons could thus be carried. In case a boat could not return at night a notice could be previously sent by bird to the ship. To what an extent this can be done is difficult to say, but from statements of other naval officers with whom he had had communication it appeared that pigeons did know their own ship, returning to it before night; and that when in harbour if their ship was suddenly sent off anywhere during their absence, on its return to that harbour they returned to the ship. Of course an isolated surveying ship would be a conspicuous mark, and if not changing its position a great number of miles a day, he thought these pigeons might be used. He had had a letter from Commander Wharton who has succeeded in partially training a young bird who returned to his ship; he also wished to state that in 1852-3, when quartered in the Channel Islands, when communication was only once in ten days (no telegraph then existing), he had used pigeons with good effect for military purposes—to obtain information required. Whenever he was called upon he would be prepared to furnish a detailed scheme for their uses at different fortresses, &c., round the coast of England.

PAPER XVIII.

TARGETS

FOR THE

TRIAL OF RECENT HEAVY ORDNANCE.

PART III.

By Colonel T. Inglis, R.E.

The Chambered 38-ton Gun against No. 40 Target strengthened with a 3-inch Plate in Front.

In the account of the trial of No. 40 target, strengthened with a fourth $6\frac{1}{2}$-inch plate, as given in Part II. of this subject (see No. 2 of the present volume), it was said that the target in that form had proved itself more than a match for the chambered 38-ton gun, and that an attempt would therefore be made to obtain a nearer measure of the penetrative power of this gun by using a 3-inch strengthening plate on the same target, instead of the additional $6\frac{1}{2}$-inch plate. Accordingly, a new 3-inch plate, measuring 4 ft. 6 ins. by 4 ft. 3 ins., was provided; and, as it would have been difficult to attach this plate to the target with a layer of teak behind it, it was decided to place it directly in contact with the front armour, and to hold it on with only such fastenings as would be sufficient to keep it in position until the shot should have done its work upon it. As thus arranged the target presented to the gun in succession a 3-inch plate, a $6\frac{1}{2}$-inch plate, a 5-inch layer of teak, a second $6\frac{1}{2}$-inch plate, another 5-inch layer of teak, and a third $6\frac{1}{2}$-inch plate.

The object of the present trial being that of repeating, as nearly as might be, the blow delivered upon the target when it consisted of four $6\frac{1}{2}$-inch plates, the conditions of Round No. 2043, as regards charge,

projectile, and range, were again adopted, only this time the charge gave a velocity of 1555 feet per second on impact, instead of 1525 feet as before, which represents an increase of energy in the proportion of 13,600 to 13,080.

The number of the round was 2067, and it was fired on the 20th July, 1877.

Unfortunately the performance of the shot was exceptionally bad, and little or nothing is to be learnt from the round. Instead of piercing the target, or very nearly piercing it, as it ought to have done, it failed even to get more than about half-way through the second 6½-inch plate, and produced no perceptible effect upon the back of the rear armour plate.

The failure of this projectile was evidently traced to its having broken up at a very early stage of its work upon the target, for the hole in the 3-inch face plate, instead of being circular and equal to the size of the shot, was an oval of about 15 inches by 13½ inches, and it was much "dished in" all round, though more on one half of the circle than on the other.

The hole in the first 6½-inch plate measured also about 15 inches horizontally by 13 inches vertically. The second or middle 6½-inch plate was deeply dished, and indented, to a depth equal to about half its thickness, in the form of a kind of double indent, by the point of the shot and by another piece of its head. The depth to the bottom of these indents, measuring from the line of original face of the target, was 2 ft. 4½ ins. The rear armour plate was driven back about 4 inches. One armour bolt, holding the middle 6½-inch plate to the rear plate, was broken in its shank by a pulling strain, the diameter at the fracture having been reduced by the strain from 2·8 to 2·12 inches, which represents a reduction of area of cross section of about 42 per cent.

From subsequent examination, it appears that the back of the middle 6½-inch plate in the neighbourhood of the shot mark is now in close contact with the rear plate, and also that the point of the shot has not got within nine inches of the back of the target.

One pile of the timber supporting the structure in rear was broken, and the strutting was more or less splintered.

The entire target was driven back five inches at the end nearest to the shot blow, and was moved forward two inches at the other end.

On comparing these results with those in Round 2039 (see Part I. of this subject, at page 4, No. 1 of this volume), in which a similar projectile, with 1140 foot tons of energy, passed through three

$6\frac{1}{2}$-inch plates; and also with the effect of Round 2043 (see Part II. at page 74, No. 2 of this volume), in which the same nature of projectile, with 13,080 foot tons of energy, got its point through three $6\frac{1}{2}$-inch plates and one inch into a fourth plate, it will be seen how large a share of the energy in this shot was lost upon the target.

It was thought by some of those who witnessed the experiment that the loose way in which the 3-inch plate was held to the face of the target had something to do with the failure of the shot on this occasion: but that explanation cannot be accepted, because, although that plate did fall off in course of the round, as was quite expected, still it did not move sideways so as to throw the shot off its balance, as was clearly seen by the way in which the bulge on its back fitted into the dish on the face of the front $6\frac{1}{2}$-inch plate.

The real explanation is that the material of the shot was bad in quality, and this is fully borne out by the appearance of the metal of the fractured shot, as well as by the great number of small pieces into which it was broken.

The only value of the experiment appears to consist in its showing how much depends upon the manufacture of Palliser projectiles being maintained at a uniform and high standard, as regards strength and hardness of metal in both head and body.

The failure of this round is much to be regretted because it is very important that we should know early what is the least amount of "plate upon plate" armour that will give protection against the battering shell of the 38-ton gun. However, it is hoped that No. 40 Target will yet afford space for another round to solve the question.

The Chambered 38-ton Gun against a Single Unbacked Iron Armour Plate, $16\frac{1}{2}$ Inches Thick.

The experiment now to be recorded was happily attended with results quite opposite in character to those of the last one.

In summing up the results of the trials with the 80-ton gun against No. 41 Target, in Part II. of this subject (see No. 2 of the present volume), it was shown that further experience as to the comparative resistances of the "plate upon plate" and "single plate" structures was very much needed.

The information upon which we had up to that time principally relied in dealing with this subject was that obtained in the trials of 1867-8, as recorded in Paper XII. of Volume XVI., and Paper XV.

of Volume XVII., of the *Professional Papers*, and the general conclusions derived from those trials were briefly these :—

1. That assuming the energy necessary for a 7-inch Palliser shot to perforate a 7-inch plate to be represented by 100, the energies sufficient for similar shot to perforate the same thickness of armour arranged in two or three layers would be as 96 and 89 respectively.

2. That these relative figures were partly verified by comparing the effect of 9-inch Palliser shot upon targets composed of two 5-inch plates and single 10-inch plates.

3. That in some comparative trials of targets consisting of three 5-inch plates and single 15-inch plates, the latter were beaten as regards resistance to repeated blows, and were only slightly superior as regards a single blow from the heaviest gun of the period.

When, however, it is remembered that these trials were made with shot striking with energies varying from 1000 to 4400 foot tons, and that now we have to deal with blows represented by the force of more than 30,000 foot tons, the necessity for obtaining data upon which to base fresh calculations becomes at once apparent.

Having obtained in Round 2039, as reported in Part I., No. 1 of this volume, so exact a measure of the penetrative power of the 38-ton gun upon a three-plate target, it was thought that we could not do better than use this result as our datum, and endeavour to obtain an equivalent result with the same gun upon a single plate. Accordingly, after due consideration of former trials, it was settled that the single plate for comparison should be $16\frac{1}{2}$ inches thick, and an iron armour-plate of this thickness, measuring 8 ft. by 8 ft., was ordered.

The final pile from which this plate was rolled was made up of seven moulds, and was 9 ft. 6 ins. long by 8 ft. 4 ins. wide, by $23\frac{1}{2}$ inches in height. The bottom mould in the furnace was 6 ins. thick, the other six moulds making up the remaining height of $17\frac{1}{2}$ inches. It may be mentioned here that the side of a plate which is undermost in the furnace, and, therefore, in the rolls also, is invariably made the back of the finished armour plate, because the upper side in cooling becomes rather the harder of the two.

The pile, as it went into the furnace, weighed about 33 tons. It was in the furnace 30 hours. The finished plate, as set up at Shoeburyness, weighed $18\frac{3}{4}$ tons.

For the trial the plate rested against supports at its top and

bottom edges to prevent its being driven back, and it was held from falling forwards by two bolts through its upper corners.

The 38-ton chambered gun was used for the trial, and it was placed at 65 yards from the plate.

The date of the trial was 1st August, 1877, and the round was numbered 2069.

The projectile was a service Palliser shell, 33·18 inches long, and 12·43 inches in diameter over the body, weighted with sand up to 817 lbs., including a gas check which weighed 11 lbs. 9 oz.

The charge used was 175 lbs. of P^2 powder, and this gave a velocity at the target of 1,410 feet per second, making the blow equivalent to about 11,260 foot tons, or rather less than that in Round 2039 which was equal to about 11,400 foot tons.

The shell struck 2 ft. 10 ins. from the left ridge, and 2 ft. 11 ins. from the top, and passed through the plate.

It made a round hole, 13 inches in diameter, and perpendicular to the face of the plate, with a lip from 2 inches to 3 inches round the front edge. It broke off the moulds on the back of the plate over an area of 2 ft. 9 ins. by 2 ft. 9 ins., and to a depth at one part of $7\frac{1}{2}$ inches. The welds of three moulds could be seen in the fractured part. From the left edge of the plate to a point near the shot hole a crack was formed extending through the whole thickness of the plate on its edge, and gaping from $\frac{1}{4}$-inch to $\frac{3}{8}$-inch.

The plate was buckled about $\frac{1}{4}$-inch on a horizontal line across its face, but only $\frac{1}{16}$-inch in a vertical line.

The plate was moved forward about $5\frac{1}{2}$ inches by the blows.

The shell was broken up into a great number of pieces in passing through, but still every part of it did get through, even including the gas check.

The quality of the metal of the shell was equal to the average of service Palliser projectiles.

An old armour-plated target in rear was a good deal scored, and indented in some instances to a depth of from $\frac{1}{2}$-inch to $\frac{3}{4}$-inch, by the pieces of the shell. A 6-inch double "paunch" mantlet which had been hung up behind the target was cut through, and a good deal damaged, and some timbers of the supports in rear were also cut through.

The point of the shell was found entire.

Comparing this result with that of round 2039, it will be seen that the shell on this occasion pierced the $16\frac{1}{2}$-inch plate with some more force to spare than that which the corresponding shell had in

it after piercing No. 40 Target in its original state. Therefore, I think it may now be fairly assumed that a solid rolled iron armour-plate of 17 inches or 17½ inches in thickness is equal, as regards resistance to perforation, to three 6½-inch iron plates separated by 5-inch layers of teak.

Also, this experiment, so far as it goes, seems to bear out the statement, made in Part II. of this subject, as to the equivalent for three 8½-inch plates, with teak between them, being probably 23 inches of solid iron plate.

For so large a plate, the heaviest and largest section ever rolled in England, the condition of the iron was quite satisfactory, and the welding good; showing that the treatment of large masses in the furnace is now better understood than it was 10 years ago, and that the means of handling them in the rolls have also been improved.

Palliser Shell at Armour-Plates separated from Masonry, and from other Armour-Plates, by Void Spaces.

In continuation of this subject, as noticed in Part II. (see No. 2 of this volume), the round against a plate standing a short distance in advance of a masonry wall, and also one against a plate at a reduced distance from another plate, can now be reported.

Taking first the masonry experiment, which took place at Shoeburyness, on the 20th of July, 1877, the wall used for the purpose was not so solid and massive as could have been wished, but it was the best that could be extemporized with the means at our disposal. It consisted of a mass of granite 14 ft. 9 ins. in frontage, 7 ft. 6 ins. high, and 3 ft. 6 ins. deep, built against the face of an old brick and Portland cement concrete wall with a good number of heavy iron cramps in it, which had formed part of a large structure built for experiments in 1864.

This brick and concrete wall was 7 ft. 6 ins. thick, making, therefore, with the granite wall in front, a total thickness of masonry of 11 ft.

The weak part of the arrangement was that of the new granite work being built without much top weight or side support, and without bond, or cramps, or dowels of any kind. Still the stone which was to receive the first shock after the shot had got through the armour plate was a good sized block, measuring 5 ft. by 4 ft. on the face, and 3 ft. 6 ins. in depth, and weighed, therefore, about 5 tons. The plate used was an old iron one, with three shot holes already in

it. It was 7 ft. 6 ins. by 3 ft. 9 ins., and 4½ inches thick. It was set up on end at a distance of 1 ft. 6 ins. from the face of the granite, and was merely blocked out from it by pieces of iron bar.

The gun used was the 38-ton gun, at 50 yards, and the projectile was the service Palliser shell, the charge being so arranged as to make the round correspond as closely as possible with the two previous rounds from this gun at void space targets, already reported.

The round was numbered 2068.

The shell struck 3 ft. 3 ins. from the bottom of the 4½-inch plate, and 1 ft. 3 ins. from its left edge, making a clean hole 13·5 to 13·8 inches in diameter, and bulging the plate outwards 6 inches on its right edge. The plate was, of course, knocked down.

The granite wall was completely wrecked; indeed, with the exception of two or three stones near its ends, nothing of it was left standing. The centre stone, already described as having been placed to receive the shot, was ground almost to powder. The brick and concrete wall in rear was cleaved asunder, with a great vertical rent about 1 foot wide in parts, and the whole structure was much knocked about, and displaced in large masses.

At first sight it appeared as if the shell had not been injured by the plate, and had passed entire into the very heart of the masonry in rear. But such was soon found not to have been the case. On turning over the pounded granite of the wall a great number of small pieces of the shell were found very near to the front, and the point of the shell itself, about 4 inches long, was recovered at a depth of only 3 ft. 3 ins. in from the original face of the granite wall. In fact, there is every reason to believe that the whole shell broke up small on first striking the granite, upwards of 240lbs. weight of small pieces of its head and body having been dug out at no great depth from the front.

Here, then, we have the double blow upon a detached plate and a granite wall producing an effect upon a Palliser shell approaching nearly to that obtained in the rounds against armour-plates with void spaces between them, already described.

That the breaking up of the shell was due to the iron plate is evident from the fact of a similar shell, in Round 2040 (see Part II.), having passed unbroken through 11 feet of masonry, of which about half was granite; and further, that it was due to the plate being *detached* may be inferred from the results of other experiments—chiefly those of 1869—reported at page 265, Vol.

XVIII., of *Professional Papers*, when 7-inch Palliser cored shot were used against 4½-inch armour-plates, which were placed at a short distance in front of a granite wall, the 15-inch interval between the plates and the wall being filled with concrete and other substances, and none of the shot broke up small.

As already intimated, the granite wall used in the present trial was very inferior to the masonry of an actual work of defence, on account of the absence of bond and want of continuity in the structure, and due allowance should be made for this in drawing conclusions from the round.

The only other trial of void space targets to be noticed in this paper is one that was made on the same date as the last, to carry out the intention, expressed in Part II., of repeating Round 2046 with a reduced distance between the 4-inch and 10-inch plates.

For this purpose the 4-inch plate, which had been used before in similar trials, was set up 1 ft. 6 ins. in advance of a small piece of 10-inch plate, measuring 3 ft. 8 ins. by 3 ft. 8 ins., which had already got one shot hole in it. Neither plate was held securely.

The 38-ton gun was again used, the charge being so arranged that the blow should be equal to those delivered against the previous void space targets.

The number of the round is 2070.

The shell struck the 4-inch plate in a sound part, 2 ft. 5 ins. from the bottom, and 2 ft. 7 ins. from the right edge, making a round hole 13 inches in diameter. It threw the plate down.

The shell then struck the 10-inch plate, 2 ft. 4 ins. from the bottom, and 1 ft. 2 ins. from the left edge. The point indented the plate to a depth of 5½ ins., splitting the plate through the indent and through the former shot hole, and breaking it into several pieces, some of which were thrown to a considerable distance. Although the point of the shell appears to have been unbroken when making the indent in the 10-inch plate, a considerable quantity of both head and body remained sticking on the face of this plate in the form of "splash," but certainly in less quantity than in the former trials of targets consisting of two armour-plates with void intervals between them. Little importance should be attached to the breaking up of the 10-inch plate in this round, because, from its small size and previous injuries, its separation represents no great amount of work.

From this trial it would appear that, at any rate with the 38-ton gun projectile, the interval of 1 ft. 6 ins. is scarcely sufficient to admi-

of the work of disintegration of the shell being carried so far as to relieve the back armour of that large share of the total work in the shell which it escaped in the rounds when the intervals were three and four times as great.

In thus noticing these void space trials it is not intended to convey the impression that they are likely to lead to any immediate results as regards the application of armour to works of fortification, for there are, in the first place, practical objections to the use of armour-plates without backing on account of their being under that condition more liable to break up than when bedded against moderately compressible substances. Also, there is the difficulty of guarding against the effect of heavy shell carrying large bursting charges of, perhaps, explosives even more violent in their action than gunpowder, into the vacant intervals. Besides, there is nothing yet to show that steel, or even improved chilled iron projectiles, would fail against these structures.

Beyond, therefore, being curious, and interesting from a scientific point of view, it is thought that the chief value of these results lies in their having shown that the limit of endurance of the service Palliser shell had been much nearer approached in the trials of late years than might otherwise have been suspected, and this will be of no slight advantage if it should lead to measures for the improvement of our armour-piercing projectiles.

Compound Steel and Iron Armour Plates.

When speaking of the trials for the Italian Government made last year at Spezia (see Part II. of this subject), attention was drawn to the comparative facility with which heavy steel plates were broken to pieces by Palliser projectiles, notwithstanding that they proved themselves superior to ordinary iron armour plates in resisting perforation by a single shell.

In this country these results attracted a good deal of attention, and the conclusions drawn from them were not generally favourable to the use of steel armour as it was applied to the Spezia targets. Still, it was plain that if by any means the advantage of the greater resistance to perforation offered by steel could be combined with the greater tenacity shown by wrought iron under sudden blows, an important step would be gained in the manufacture of armour plates for use, at any rate, in floating structures.

Accordingly, the English armour plate makers set themselves to work upon this problem; and, to assist them in their operations,

they were allowed to send their sample plates, as they made them, to Shoeburyness for proof, under the system there established for fortification purposes.

Although these operations have not yet passed beyond the experimental and preliminary stage, it may still not be amiss to give here a short account of what has been done in the matter up to the present time.

The first trials were made with small plates of soft steel, produced by the Bessemer process, and rolled direct from the ingots. Of these one tempered in water at red heat gave better results than those untempered; but still, at the best, there was too much tendency to crack in these plates, and not sufficient hardness to break up the heads of the Palliser shell.

Another plate made from a Bessemer ingot of soft steel, squeezed in a press and afterwards rolled, and cooled in sand, broke up into a number of pieces.

Also a 5-inch iron plate carburized on its face to a depth of $\frac{3}{4}$-inch, and on its back to a depth of $\frac{1}{2}$-inch, in a converting furnace, broke up unsatisfactorily.

At a subsequent period an attempt was again made to convert the face of a 5-inch iron plate into steel: but, in this case also, the back became carburized as well as the front, the former to a depth of $\frac{1}{2}$-inch, the latter to a depth of $\frac{1}{4}$-inch, and the plate did not give good results at Shoeburyness.

After this the process of welding steel and iron together into a compound mass was once more taken up.

The object to be gained by this combination, in the case of armour plates, is simply that of presenting to the projectile a hard face, against which its force may be expended, and itself broken up, if possible, at an early stage of its work upon the armour; while, in order to counteract the effect which sudden blows will always have upon hard steel, or rather in order to hold the steel together after it may have been cracked by the shot, a soft and ductile wrought iron back is provided.

On referring to Vol. XVI. of the *Professional Papers*, Paper XII., it will be seen that an extensive series of experiments took place at Shoeburyness, in 1867, with plates of steel and iron welded together, but the general result was that the compound plates could not compete with the ordinary soft rolled iron armour.

The difficulty then experienced was that which, it is well known, has always attended the welding of iron to steel, namely, that of

dealing with two kinds of metal, which weld at different temperatures; which difficulty is aggravated in the case of the two metals containing widely different proportions of carbon, as in *hard* steel having to be united to *soft* wrought iron.

The failure of the steel and iron plates in 1867 brought such manufacturing difficulties to light that no further attempts were made for some time in that direction, at any rate with masses of metal of any considerable size.

But of late years steel and wrought iron have been very perfectly welded by pouring the steel in a molten state on to the iron, previously raised to a white heat; and this process has, I believe, been successfully applied to the manufacture of railway material, and to other purposes.

Improving upon this mode of manufacture a process has been devised at the works of Messrs. Cammell and Co., of Sheffield, which Mr. G. Wilson, the managing director of the firm, has obligingly described to me in the following terms.

"Since the trials at Spezia the inherent difficulty in welding large masses of steel and iron has been overcome by Mr. Alexander Wilson, by pouring steel in the melted state upon the surface of an iron plate when it has been heated to a good red heat. The temperature of the molten steel being much in excess of the welding heat of iron, the surface of the heated iron plate becomes partially fuzed by the overlying liquid steel, and thus a complete union or weld between the two metals is obtained—there being practically no limit to the masses of metal used.

"In this case the weld is not limited to a simple line marking the difference between the steel and the iron, as is the case in all ordinary welds, but a third metal or semi-steel is formed between the two, varying in thickness from $\frac{1}{8}$-inch to $\frac{3}{16}$-inch, by the carbon of the steel running into the iron, and through the formation of this semi-steel, the two metals are joined together inseparably, or, in other words, the steel has run gradually into the fibrous iron and the iron into the steel.

"Experiments have been made to ascertain the relative strength of this weld, and on every occasion the iron only has been torn asunder out of the solid, while the weld itself has remained intact."

Two small armour plates made upon this plan were sent by Messrs. Cammell for test at Shoeburyness in July last. Each measured 3 ft. 6 ins. by 3 ft. 10 ins., and 9 inches in thickness. One had a 5-inch face of hard steel, containing ·64 per cent. of carbon, and a 4-inch

wrought iron back, and was hammered. The other had a $4\frac{1}{4}$-inch face of somewhat softer steel, containing ·48 per cent. of carbon, and a $4\frac{3}{4}$-inch back of wrought iron, and was rolled. They were made by heating 7-inch rolled iron plates to a good red heat, and quickly transferring them to a cast iron mould or box. Molten steel was then poured upon the wrought iron to a depth of 8 inches, so that the combined ingot thus formed was 15 inches in thickness. The masses were then reduced, by hammering and rolling as above-mentioned, to the finished thickness of 9 inches. The slight difference between the thickness of the steel in the two plates was accidental, or perhaps the difficulty of judging where the division between the steel and iron occurred will account for the difference of thicknesses recorded.

They were tried with 7-inch service Palliser shot, weighing 113 lbs., and fired with 30 lbs. of pebble powder, at 30 yards.

With regard to the first, that is the one with the hard steel face, the indent was only 3·2 inches deep. The shell broke up in its head as well as in its body, and the plate was scored by it all over its face.

The fragments of the shot were hot when picked up. Five cracks radiating from the indent were formed in the plate. One of these was 7 inches deep as measured on the edge of the plate, another 5 inches, the other three were fine cracks and of less depth. The area of the shot mark on the face of the plate was $9\frac{1}{2}$ inches in diameter. In rear the bulge was local, and only $\frac{3}{10}$-inch high, and there were no cracks at all.

The welding of the steel to the iron was very perfect, and showed no signs of giving way in any part.

The slightness of the indent is remarkable. The corresponding indent in a 9-inch wrought iron plate of best quality, under similar circumstances, is generally from $12\frac{1}{4}$ inches to complete perforation. By the completeness of the welding the effect of the cracking of the steel was neutralized to some extent by the wrought iron, while the hardness of the steel led to the breaking-up of the projectile, and the consequent loss of work upon the plate.

With regard to the second of these plates, namely, that with the soft steel face, the shell in this case made an indent 5·45 inches deep. The head of the shell was much broken, and the body was also broken up small, but the destruction of this projectile was not so complete as was that of the shell against the other plate. In this instance there were four radiating cracks, $7\frac{1}{2}$ inches, 4·7 inches, 4·7 inches, and 4·5 inches deep from the face respectively. In rear, the

local bulge was ·85-inch high, and there were faint cracks, with a gape of ½-inch at the widest part, on the bulge. The welding of the steel to the iron was undisturbed in this case also.

It may be mentioned that Messrs. Cammell & Co. made another small 9-inch plate about this time, which was composed of a 5-inch hard steel centre between 2-inch soft steel at front and back; but this plate, although it was only indented 4·8 inches deep by the 7-inch shell with 30 lbs. of pebble powder, broke up into four pieces. The head of the shell in this instance remained entire, but the body was splashed against the plate. When first picked up the head was cool, but it grew warm afterwards.

This plate was made by casting the steel in layers, each layer being allowed to set before the next was run upon it, and the mass was afterwards rolled down to its finished thickness. From the appearance of the fractures at proof, the hard and soft steels seem to have become fused together, and the metal was homogeneous throughout.

Messrs. Brown and Co., of Sheffield, also made two small plates by heating equal masses of hard Bessemer steel and wrought iron in an ordinary furnace, and rolling them down to five inches in thickness, borax being used as a flux. Thus the plates were half of steel, containing 0·5 per cent. and half of wrought iron. One of these plates was hardened in water, and the other was unhardened.

The indent from a 7-inch Palliser shell, weighing 113 lbs, fired with 8½ lbs. of R.L.G. powder, at the hardened plate, at 30 yards, was 3·35 inches, or just half the depth of the usual indent from the same blow on a 5-inch rolled iron armour plate of A 1 quality. A 7-inch shell fired with 25 lbs. of pebble powder got its point through this plate. The welding of the steel to the iron was not so perfect as in the 9-inch plates lately described. The head of the shell remained whole, but the body broke up small.

The plate that was unhardened was indented 3·4 inches, as against 3·35 inches in the hardened one. A 7-inch shell, fired with 20 lbs. of pebble powder, penetrated this plate and broke it in two. The welding was somewhat better in this case, but neither of the plates was altogether satisfactory. It was thought that the resistance offered by these plates to perforation was about equal to that of a soft iron armour plate 8 inches thick.

Just as this account was completed Messrs. Brown and Co. sent for trial another compound plate, made in the following manner. A 9-inch rolled iron armour plate was laid in an ordinary furnace, and upon this was placed a wrought iron frame, made of bar, 7 inches

high and 4 inches wide, running all round the plate close to its edges. When at a red heat the plate with its frame still upon it was brought out of the furnace, and hard Bessemer steel, containing 0·5 per cent. of carbon, was run in a molten state upon the iron armour until the tank formed by the frame was full to the brim. By the heat imparted to the wrought iron by the steel the frame and plate were brought to welding heat and united, and the steel and iron were also welded as in the other experimental plates already described. The mass was then allowed to cool, and was afterwards reheated and rolled down to a 9-inch plate, of which the front four inches were of steel. It was then cut to the usual dimensions of proof plates, namely, 3 ft. 10 ins. by 3 ft. 8 ins.

The 7-inch Palliser shell, fired with 30 lbs. of pebble powder, at 30 yards, indented the plate to a depth of 4·5 inches, and raised a bulge on the back $\frac{3}{10}$-inch high and 13 inches across. There were six radial cracks formed through the steel, stopping at the wrought iron frame at the edge of the plate. The head and body of the shell were broken into small pieces.

These being the principal results of the preliminary trials, the manufacturers have, on the experience thus gained, made some large compound plates for the Admiralty, for comparison with rolled iron plates and steel plates, and it is hoped that the trial of them will come off before very long.

T. INGLIS,

9th November, 1877. COLONEL, R.E.

PAPER XIX.

THE CYCLOSCOPE.

By Lieut. G. S. CLARKE, R.E.

The problem of devising a means of ascertaining at any moment the speed of a revolving body has received numerous more or less successful solutions. If a trustworthy constant rotary motion can be obtained to be used as a standard, an epicyclic train can be made to give the desired indications. There is, however, a great difficulty in obtaining a motion which will remain constant even for a short period of time. Again, a small centrifugal pump will maintain a greater or less column of water as the speed at which it it driven increases or diminishes. Further, in the strophometer, an instrument which has been used successfully on some ships of war, two heavy balls linked to a vertical axis, like those of the ordinary governor, tend to fly outwards in proportion to the square of their velocity, and, in so doing, move an index arm traversing over a figured dial.

In the instrument about to be described, which has been devised by Professor H. McLeod and the writer, the standard motion is vibratory, and is given by a tuning fork, or reed, the period of which, though not absolutely constant as will be noticed hereafter, is liable to but slight alteration.

If a pointer attached to one limb of a tuning fork is placed so as just to touch a smoked drum driven by the machine whose speed is to be measured, it will trace out a wave line of the form shown in *Fig.* 1, *Plate* I.

The portion from *a* to *b* is traced during one vibration of the fork and the distance apart of the crests of adjacent waves will depend upon the velocity of the drum, becoming greater as that velocity

increases. Suppose that the perimeter of the drum is 10″, the period of the fork 60 vibrations per second, and that five complete waves occur in a length of one inch of perimeter. Then evidently $\frac{1}{10}$ of a complete revolution takes place in $\frac{1}{12}$ of a second. The speed of the drum is, therefore, 72 rotations per minute.

Practical difficulties would arise in utilizing this method, and, moreover, it would be necessary to stop the drum in order to make an observation, and then either to measure off on the perimeter of the drum the length occupied by a given number of vibrations, or to count up the number of vibrations taking place in a given length of perimeter. This operation would in most cases be too tedious. An optical method has therefore been adopted, which has been found to give excellent results.

If a number of dots at equal intervals are viewed in a mirror, or through a lens attached to a tuning fork, then, in virtue of the retention of their images on the retina the dots will appear as straight lines. Thus the images of the dots shown in *Fig.* 2 will appear drawn out into the lines shown in *Fig.* 3, if the fork is so placed that the motion of the images is at right angles to a line through the dots.

If, further, a motion is given to the dots at right angles to the direction of vibration of their images, the two combined rectilinear motions will produce the appearance of a sinous line, or wave form.

The height of the wave will depend on the amplitude of the vibration of the fork, while the wave-length will depend on the relation of the speed of the dots to the period of the fork. The greater the speed of translation of the dots becomes, the greater will be the wave-length.

If certain exact ratios obtain between the velocity of the dots and the period of the fork, the waves formed will be absolutely stationary. If the velocity of the dots is slightly greater or less than that required for the fulfilment of these ratios, the wave will be the same in form as that which the exact ratio would give, but it will have a slow progressive motion. This progressive motion will be in the same direction as that in which the dots move if the velocity of the latter is too great, and in the reverse direction if it is too small for the exact ratios.

The laws governing the ratios on which the formation of stationary waves depends may be stated as follows :—

If the velocity of the dots is such that the time occupied by each dot in passing over the interval between two adjacent dots, is exactly

equal to the period of one complete vibration of the fork or reed, a single stationary wave (*Fig.* 4*a*) is produced.

If the time occupied by each dot in passing over *two* intervals is equal to the period of one complete vibration, the wave traced by the image of each dot will pass through the position of the adjacent dot, and as each dot will trace a wave of its own, a double wave (*Fig.* 5*a*) compounded of two single waves will result.

Again, if a complete vibration takes place in the time of passing of a dot over three or four intervals, triple and quadruple waves (*Figs.* 6*a*, *Plate* I., and 7*a*, *Plate* II.) will respectively be formed.

Similarly, waves compounded of five, six, seven, and eight waves may occur under suitable conditions as to the velocity of the dots. There is, in fact, theoretically, an infinite number of compound waves. The eighth compound wave has been actually observed; but the production and maintainance of the more complex forms requires a regularity of motion which it is very difficult to obtain.

It will be evident that waves of the same form as those above defined can be obtained with other velocities. Thus, if *two* complete vibrations occur in the time of passing of a dot over *one* interval, another single wave (*Fig.* 4*b*) is produced. Similarly, if *three* complete vibrations take place in the time of passing of a dot over *two* intervals a new double wave (*Fig.* 5*b*) results. Again, a triple wave (*Fig.* 6*b*) occurs when *two* complete vibrations occur in the time of passing of a dot over *three* intervals, and a quadruple wave (*Fig.* 7*b*) if *three* vibrations take place in the time of passing of a dot over *four* intervals. There is, theoretically, an infinity of series of waves, and an infinity of waves of the same form in each series.

The form of the wave determines at a glance the series to which it belongs, while differences of wave length and of brilliancy distinguish between waves of the same series.

The first or primary wave in each series (*Figs.* 4*a*, 5*a*, 6*a*) has the greatest brilliancy, while it requires the greatest velocity of the dots for its formation.

The laws of formation of the different waves may be stated as follows:

1.—*Single wave*, any whole number of complete vibrations in the time of passing of a dot over *one* interval.

2.—*Double wave*, 1, 3, 5, 7, etc., complete vibrations in the time of passing of a dot over *two* intervals. Any whole number of vibrations not divisible by 2.

3.—*Triple wave*, 1, 2, 4, 5, 7, etc., complete vibrations in the time of passing of a dot over *three* intervals. Any whole number of vibrations not divisible by 3.

4.—*Quadruple wave*, 1, 3, 5, 7, 9, etc., complete vibrations in the time of passing of a dot over *four* intervals. Any whole number of vibrations not divisible by 2 or 4.

And so on for more complex forms.

The above laws may also be expressed as follows:—Denoting the velocity of the dots required for the formation of the primary wave of the first series by unity; the velocities required to produce other waves will be—

1st	Series	$1, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}$ . . . . .
2nd	„	$2, \frac{2}{3}, \frac{2}{5}, \frac{2}{7}, \frac{2}{9}$ . . . . .
3rd	„	$3, \frac{3}{2}, \frac{3}{4}, \frac{3}{5}, \frac{3}{7}$ . . . . .
4th	„	$4, \frac{4}{3}, \frac{4}{5}, \frac{4}{7}, \frac{4}{9}$ . . . . .
5th	„	$5, \frac{5}{2}, \frac{5}{3}, \frac{5}{4}, \frac{5}{6}$ . . . . .

It remains to show how the principles above laid down can be utilized in a practical form.

Suppose that a drum carrying 100 dots, equally spaced round its perimeter, rotates in front of a reed or fork, giving 60 complete vibrations per second, the latter being so placed that the images of the dots are displaced in a direction at right angles to their motion, or parallel to the axis of the drum. If then the drum is driven at such a speed that the primary single wave appears stationary, it will be evident that 60 dots per second, or 3600 per minute, must be passing in front of the vibrating lens or mirror, but as in one complete revolution of the drum 100 dots pass, the speed of the drum must be $\frac{3600}{100} = 36$ revolutions per minute. Again, if a primary double wave appears stationary the speed of the drum is evidently $\frac{2 \times 60 \times 60}{100} = 72$ per minute, while a primary triple stationary wave would require a velocity of $\frac{3 \times 60 \times 60}{100} = 108$ per minute, and so on. By referring to the above table the speed required to produce any other wave can be obtained. For practical purposes the primary double wave seems best adapted. Its form is easy to recognise, and its superior wave length and brilliancy serve to distinguish it from other waves of the same series. Moreover, a symmetrical form which gives bright points, or crossings along its centre line possesses advantages. If t is the number of complete vibrations of the fork

or reed per second ; v the number of rotations per minute of the dotted drum, and n the number of dots ; then a stationary primary double wave will be produced, if

$$v = \frac{2\,t \times 60}{n}^{*}.$$

From this equation v, n, or t can be found if two of them are known. If, therefore, it were required to read velocities of from 20 to 40 revolutions per minute, it would be necessary to place round the drum a series of rings of dots containing—

$$\frac{2\,t \times 60}{20}, \quad \frac{2\,t \times 60}{21}, \quad \frac{2\,t \times 60}{22}$$

etc., dots each. If then any ring, say the 5th from the ring corresponding to a velocity of 20, gave the stationary double wave, it would be certain that the speed of the drum was 25.

A practical difficulty arises, however, in placing such a series of dots round a drum, for instance, with a 60 fork, or reed, the perimeter of the drum would have to be divided into 342·8571 intervals, in order to obtain a stationary primary double wave with a velocity of 21 per minute, and, moreover, even if such a division were practicable, it would not be possible to read off speeds intermediate between whole numbers of rotations per minute, *e.g.*, 21½. It becomes necessary, therefore, to adopt some other method.

If, instead of dots, equidistant lines are placed round a drum, parallel to its axis, and are observed through a slit attached to a fork, or reed, precisely similar waves to those above described are formed. A piece of paper is prepared by ruling lines as in *Fig.* 8, *Plate* II., which all converge in a point o, and pass through equidistant points on the line $a\,b$, and a rectangular portion $c\,d\,e\,f$ of a size sufficient to wrap round the drum is cut out. These lines, when viewed, through the slit, act as an infinite series of dots equidistant in each series, and exactly fulfil the requirements above indicated. Thus, if the convergent lines are so drawn that their intervals on $c\,e$ are such as to suit the maximum velocity V, and the intervals on $d\,f$, the minimum velocity v to be measured, then between $c\,e$ and $d\,f$ there will be position which will give stationary waves for every velocity between V and v. Moreover, equal distances along the drum correspond to equal differences of velocities ; thus, if V is 60 and v 20

* This equation may be put in the general form $v = \frac{60\,C\,t}{n}$ where C is a co-efficient depending on the series to which the wave belongs and on the particular number in that series. The table, page 4, gives the values of C for different waves.

rotations per minute, the positions corresponding to velocities of 50, 40, and 30 will be found by simply dividing *c d* into four equal parts, and by further subdivision the positions corresponding to all velocities between *V* and *v* can be obtained.

In the Cycloscope, as at present constructed, a box *a* (*Plate* III.), containing a reed, to the tongue of which a piece of very thin zinc, with a slit, has been soldered, moves in front of a drum, carrying a paper ruled with lines in the way described. The motion is given by the hand-wheel *b* to a pinion *c*, on the same axis, the pinion gearing into a rack attached to the slide *d*.

The reed box carries a small pointer *p*, which traverses a scale *s s*. The period of the reed is 60 complete vibrations per second. The ruled paper is prepared as follows :—Suppose that the perimeter of the drum is P, its available length L, and that the range of velocities which it is desired to measure is from 120 to 60 rotations per minute. A line of length P, is divided into $\frac{7200}{120}$ (= 60) equal parts. Then, if *h* (see *Fig.* 8, *Plate* II.) is the distance from *o* to the line corresponding to a velocity of 120—

$$\frac{h}{h - \mathrm{L}} = \frac{\frac{7200}{60}\mathrm{P}}{\frac{7200}{120}\mathrm{P}} = 2$$

whence $h = 2\,\mathrm{L}$. The point *o* on which the lines are to converge must, therefore, be taken at a distance 2 L from the divided line. The lines are now drawn sufficiently far to cover a breadth of paper equal to L, and in order that a rectangle equal to the development of the whole drum may be covered with lines, it will be necessary to produce the divided line and carry the divisions out further each way. White lines ruled with Chinese white, on a black or blue ground, and varnished after mounting with thin spirit varnish, have been found to answer very well. These lines should be about the same breadth as the slit. The paper so prepared is pasted on to the drum, and it is convenient, but not essential, to arrange it so that the centre line *o n* (*Fig.* 8, *Plate* II.) falls on the drum exactly opposite the junction, each line cut by the line *c d* will then be met by a similarly situated line cut by *e f*, and the junction will present the appearance shown in (*Fig.* 9, *Plate* II.)

The graduation of the scale should be performed *after* the mounting of the paper, in order that no error may arise from stretching of the latter. If a circle is traced round the drum at any of the intersections shown in *Fig.* 9, this circle will be divided into equal parts. Starting at any two intersecitons the lines are counted round and found to be *N* and *n* respectively, the speed required to produce the

stationary double wave at these positions will be $\frac{2 \times 60 \times 60}{N}$ and $\frac{2 \times 60 \times 60}{n}$ respectively. The scale can, therefore, be marked at these two points, and the intermediate graduations can be obtained by subdivision.

A vernier could be employed in place of the pointer *p*, by which the primary divisions could be subdivided into 10 or 100 parts.

Referring to *Fig.* 9, it will be evident that only at the intersections, and at one intermediate point between each pair, will circles traced round the drum be divided into a whole number of equal parts. Circles traced at other positions will have one unequal division at the line of junction; this will cause a slight movement, or jump, of the wave at each rotation of the drum. This cannot, however, be mistaken for the steady progressive motion denoting that the position corresponding to the stationary curve has not been arrived at.

To make a reading it will now be necessary to start the reed and to move the hand-wheel *b*, until a stationary double wave is seen; the pointer will then indicate the speed.

To make the waves more visible, two small lenses *c c* are employed, fixed in the front and back of the reed box. The lens on the back of the box throws an image of the lines on the slit; that in front magnifies this image, and thus parallax is avoided. If the instrument is to be used in a dark situation, a small lantern is placed on the bracket *t* attached to the side of the reed box, in order to illuminate the portion of the drum under observation.

The reading can be made without taking the eye from the front lens, if a scale identical with that described is placed close in front of the drum, at such a height that its graduations can be seen through the slit, when the latter is set in vibration. It may be advantageous, in some cases, to place the ruled paper on a shaft, instead of attaching it to a drum driven by a belt and pulley; indeed, one of the great merits of the principle is that it can be thus *directly* applied to a machine, without the intervention of any mechanical transmission. In such a case it may be impossible to bring the apparatus close up to the shaft. If, however, the fork or reed vibrates in the focus of the object-glass of a small telescope, the observation can be made at a considerable distance from the shaft. The plan of placing the scale close up to the drum would then have to be employed, and it will be advisable to trace circles round the drum, each circle denoting the position corresponding to an integral

number of rotations per minute. The slight error due to parallax would thus be obviated.

In the early experiments it was found difficult to keep up a sufficient supply of air to the reed without a considerable pumping power and large conducting tubes. By the utilization of the principle of the injector, or jet pump, this difficulty has been entirely removed. The air is supplied through a small flexible indiarubber tube from a pair of foot bellows. This tube terminates in a small glass tube drawn out to leave a narrow jet, $1\frac{1}{2}$ mm. in diameter. This fine jet is passed through a cork, fitted into a wide brass tube *k* (*Plate* III.) fixed into the lower part of the back of the reed box. The lower part of the brass tube is cut away to allow free access to the surrounding air. The arrangement is shown in enlarged section in *Fig.* 10, *Plate* II.

Air, of pressure about equal to a column of water 20 or 25 c.m. in height, is forced through the jet, and the reed vibrates perfectly, the mean pressure of air in the reed box being only about equal to a column of water $1\frac{1}{2}$ mm. in height.

In the original experiments it was necessary to devise a means for readily setting tuning forks in vibration. The arrangement shown in *Fig.* II. was found to answer remarkably well. A short piece of soft iron, with its ends turned up in opposite directions, is carried on an axis between the prongs of the fork, the latter being surrounded by a wooden box, to which the bearings of the axis are fixed. The bar forces the prongs apart, as shown in the figure, and when the axis is sharply turned through 90°, the fork is set in vibration.

It has so far been assumed that the period of a fork or reed is absolutely constant. This is not the case, as the fork varies slightly with temperature, vibrating more slowly as the metal becomes warmer. In some experiments made with tuning forks a loss ·011 per cent. per 1° Centigrade was observed. This would be too small to affect the value of the instrument for practical purposes, while, if it were employed for delicate investigations, a correction could readily be applied. Temperature similarly affects reeds, their period is also lengthened by an increase of pressure of the air by which they are set in vibration. By the employment of the air injector described in a foregoing paragraph, any considerable variation in the pressure of the air supplied is prevented. The mean of 22 fairly concordant observations gave ·010 per cent. for each degree Centigrade as the loss occasioned by rise of temperature. The deter-

minations of the effect of temperature above alluded to were carried out by means of Lissajous' figures, and it may be mentioned that the latter can be produced by attaching pieces of paper with very fine slits to the forks, in place of mirrors as has been the usual practice hitherto. One fork is placed horizontally and the other vertically, a fixed lens being mounted between them, so as to form an image of one slit on the other. The great advantage of this plan is that with large forks the influence of the additional weight of the paper and attaching gum is inappreciable.

There are several methods of determining the absolute period of a reed or fork. These are described at some length in a paper communicated by Mr. A. J. Ellis, F.R.S., to the *Journal of the Society of Arts* for May 25th, 1877. The absolute period of a standard fork or reed being obtained, there is no difficulty in optically tuning any other number of forks or reeds to the same pitch.

The principle of the Cycloscope is now being employed in the construction of an apparatus for determining the absolute pitch of a fork or reed, and the experiments so far have given excellent results. If a steady rotary motion capable of perfect control is given to a drum carrying a ring of lines, and if the motion is so regulated that any recognised wave, given by a fork or reed of unknown period, is kept stationary during a measured interval of time, the exact number of rotations of the drum during this interval being accurately recorded, then evidently the period of the fork or reed can be obtained. It is not even necessary to attach a slit to the fork, as the edge of the latter is found to answer equally well.

Three determinations of the period of a 256 fork, made by Professor McLeod, gave the numbers 256·287, 256·281 and 256·287 vibrations per second; a 320 fork gave 320·364; a 384 fork 384·456, and a 512 fork 512·549. These numbers must be regarded as merely preliminary, as known imperfections exist in the apparatus.

The essential feature of the cycloscope is its extreme delicacy; this, while unfitting it for observations where it is required merely to read average speeds, renders it specially useful in cases when it is necessary to determine the absolute speed of a rotating body at a given instant.

For example, in Noble's chronoscope for measuring minute intervals of time, a number of discs are driven at a very high speed, and the breaking of electric circuits carried through the gun itself, or through screens in front of the muzzle, causes sparks to pass, and to mark the edges of the discs. If then the speed of the discs is known

with certainty at the precise instant of firing, the distance between the marks on the discs gives a very accurate measure of the interval which has elapsed between the breaking of the circuits. All experiments with the Cycloscope tend to show that a constant rotary motion cannot be obtained, and that with the best machinery slight variations are occurring at every moment. In such a case as this it is particularly unsafe to trust to an average velocity, as it is quite possible that at the moment of firing, the actual velocity may differ very considerably from the average. If, however, to some portion of the machinery a wheel is attached, the circumference of which is accurately divided by a number of lines, then by observing these lines through a slit attached to a suitable fork or reed, it can be seen at a glance whether the machinery is running regularly. It will be necessary to apply some simple friction regulator which can be controlled by the observer; the *direction* in which the wave moves showing whether the speed is too high or too low for the stationary wave. Directly the wave has been brought to rest by the application of the break, the firing key which may be in charge of the same observer is put down.

Some interesting experiments have been made with discs on the principle of the thaumatrope, which in one direction at least promise results of practical utility.

If a disc provided with slits is driven at a constant speed by clockwork in front of another disc provided with a ring of dots or symbols, then, when the number of slits passing in front of the eye in a given time is equal to the number of dots which pass in the same time the latter will appear to be stationary.

Thus, if N and n are the number of rotations of the clock and machine discs per minute respectively, S the number of slits, d the number of dots.

When $NS = nd$; d dots will be visible and stationary. Thus S and N being given or assumed, d can be obtained for any assigned value of n.

If the machine disc is running a little too fast for the above equation, the dots will appear to move slowly in the *same* direction as this disc; if too slow, they will move in the *opposite* direction.

If $NS = 2\,dn$; $2\,d$ dots will be visible and stationary.

If in place of dots symbols alternately alike are employed thus—

then, by reason of the superposition of adjacent symbols, when $S N = 2 d n$ the appearance is 2 d stationary,

X X X X X

where d is the *whole* number of symbols employed. Although the difficulty above alluded to, of obtaining a trustworthy standard rotary motion, places difficulties in the way of using this method for the *absolute* measurement of velocities, there is no reason against its adoption for the investigation of the *relative* speeds of two machines.

Thus, in the case of the twin engines so largely used on modern ships of war, by merely driving one disc from each engine a glance will show whether the two engines are running together, and if not, which is the faster. Moreover, by a suitable arrangement of symbols the same discs could be made to show whether the speeds of two such engines bear any simple ratios as 1: 2, 1: 3, 1: 4, etc., to each other. In the elucidation of the many difficult problems connected with steering this method promises to be useful.

Other applications of the principle of the Cycloscope might be adduced, but enough has been said to give some idea of its power and general adaptability.

To all cases where it is necessary to study carefully the working of a machine, the method can be applied with advantage, while its great elasticity permits it to be adapted to high or low speeds, long or short ranges of velocity, heavy engine machinery or light clockwork with equal facility.

G. S. CLARKE,
LIEUT., R.E.

NOV 14 1916

PL. I.

Fig. 1.

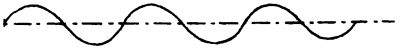


Fig 2.

Fig 3.

Fig 4.

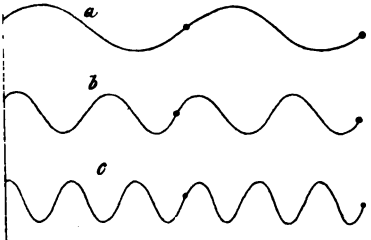


Fig. 5.

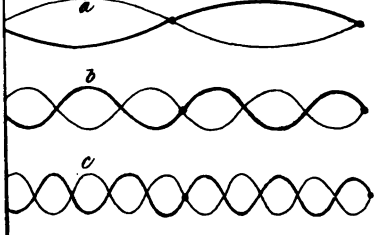


Fig. 6.

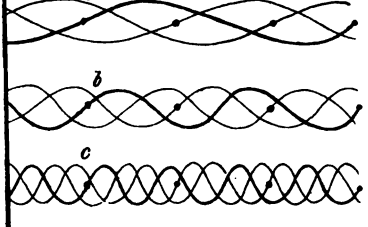


Fig. 7.

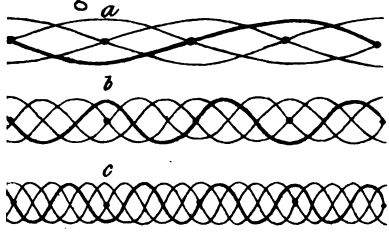


Fig. 8.

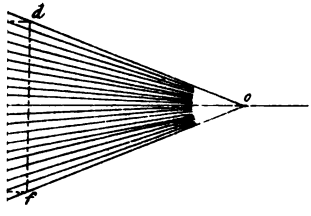


Fig. 11.

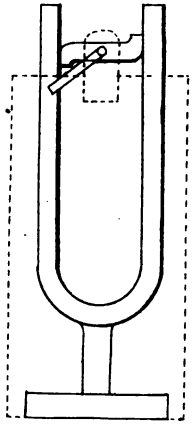
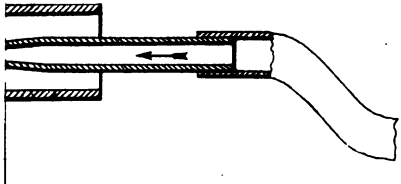


Fig. 9.

Fig. 10.



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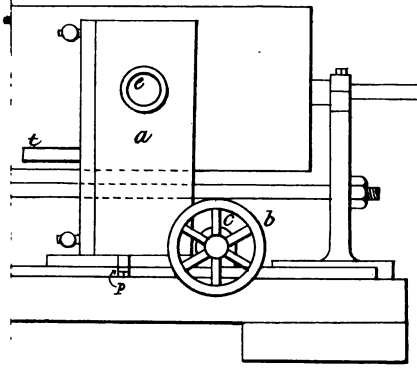
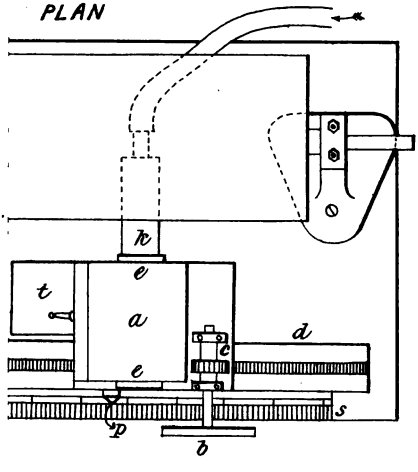


PLAN



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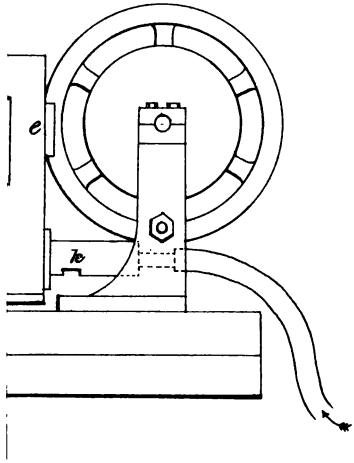

NATURE OF ORDNANCE.			Mark of latest pattern	Service.	Nominal Weight. ton.	cwt.	lb.	Nomin Length ft.	in.
Muzzle-loading.	Breech-loading. Screw	7-in. ...	...	L.S. & S.S.	0	82	0	10	0
		,, ...	...	L.S.	0	72	0	9	10
		40-pr. ...	...	L.S. & S.S.	0	35	0	10	1
		,, ...	...	L.S. & S.S.	0	32	0	10	0
		20-pr. ...	...	L.S.	0	16	0	8	0
		,, ...	...	S.S.	0	15	0	5	6·1
		,, ...	...	S.S.	0	13	0	5	6·1
		12-pr. ...	...	L.S. & S.S.	0	8	0	6	0
		9-pr. ...	...	L.S. & S.S.	0	6	0	5	2
		6-pr. ...	...	L.S. & S.S.	0	3	0	5	0·1
	Bronze,	7-pr. ...	II.	L.S. & S.S.	0	0	200	3	0
	Cast-iron.[a]	$\frac{80}{65}$-pr.[c] ...	I.	L.S.	5	0	0	10	0
		$\frac{64\text{-pr.}^c}{8\text{-in.}}$ ...	I.	S.S.	0	71	0	9	0
		$\frac{64}{32}$-pr.[c] ...	I.	L.S.	0	58	0	9	6
	Wrought iron.	16-in.[b] ...	I.	S.S.	80	0	0	26	9
		12·5-in...	I.	L.S. & S.S.	38	0	0	18	9·5
		12-in. ...	I.	L.S. & S.S	35	0	0	15	11·7
		,, ...	I.	L.S. & S.S.	25	0	0	14	3·5
		11-in. ...	II.	L.S. & S.S.	25	0	0	14	2
		10-in.[l] ...	II.	L.S. & S.S.	18	0	0	14	2·7
		9-in. ...	V.	L.S. & S.S.	12	0	0	12	3
		8-in. ...	III.	S.S.	9	0	0	11	4·5
		7-in. ...	III.	L.S.	7	0	0	11	9·5
		,, ...	III.	S.S.	6	10	0	10	6
		,, ...	I.	S.S.	0	90	0	10	4·5
		64-pr.[c] ...	III.	L.S. & S.S.	0	64	0	9	3·5
		40-pr. ...	I.	L.S.	0	34	0	8	0
		,, ...	II.	L.S.	0	35	0	9	6·7
		25-pr. ...	I.	L.S.	0	18	0	7	10·5
		16-pr. ...	I.	L.S.	0	12	0	6	2·4
		12-pr.[b] ...	I.	L.S.	0	8	0	6	9·6
		9-pr.[l] ...	I&II	L.S. & S.S.	0	8	0	5	8·5
		,, ...	I.	S.S.	0	6	0	4	10
		,, ...	II.	L.S.	0	6	0	5	11
	Steel ...	7-pr. ...	III.	L.S.	0	0	150	2	2·5
	,,	,, ...	IV.	L.S. & S.S.	0	0	200	3	2·9
	Howitzer,	6·3-in.	I.	L.S.	0	18	0	4	6
	,,	8-in...	I.	L.S.	0	46	0	5	1·1
	,,	10-in.[b]	I.	L.S.	6	0	0	6	5·5
Gatling Gun,		0.45	Nil.	L.S. & S.S.	0	3	108	4	11·4
,,		0·65[j]	,,	S.S.	0	7	35		

a Inner barrel of coiled wrought-iron. *b* Not yet in the se

l These guns are not interchangeable, on account of a slight differe

be used when P. gunpowder is not available. *m* An 8 oz. char

RGE.[m]								
	Service.				SHOT.		
			er.				
				M.L.O.				
	L.G.	Common.	20 secs.	9 secs.	Case.	Grape.	Solid, loose.
	lb. oz.	lb. oz.			lb. oz.	lb. oz.	lb. oz.
	4 0	8 9	...	..	16 15¼	.....	12 8
	2 8	.....	...	...	13 9	.....	9 4
	1 8	.....	...	...	8 6	.....	6 3
	0 12	.....	...	...	4 7	.....	3 1½
	0 10	.....	...	...	4 7	.....	3 1½
	3 0	22 5	...	...	21 7	.....	.....
	2 8	16 12	...	...	13 13	.....	.....
Bron	1 4	8 9	...	...	7 14	.....	.....
	0 8	8 9	...	...	8 1	.....	.....
	0 7	.....	...	...	.....	.....	.....
	0 5	.....	...	...	.....	.....	.....
	5 0	47 4	...	...	48 1¼	46 8¼	.....
	3 2	29 11	...	...	35 6	38 2	

TABLE SHOWI[illegible]ER FROM HEAVY RIFLED M.L. GUNS.

[CORRECTI[illegible]

TABLE III.

Range.	12-inch R.M.L. Charge, 11[illegible] Projectile, [illegible] tons.			8-inch R.M.L. of 9 tons. Charge, 35 lbs. Projectile, 180 lbs.			7-inch R.M.L. of 6½ tons Charge, 30 lbs. Projectile, 115 lbs.		
	v.	Total energy.	[illegible]ergy r inch shot's cum-ference.	v.	Total energy.	Energy per inch of shot's circum-ference.	v.	Total energy.	Energy per inch of shot circum-ference
yds.	ft.	ft. tons.	tons.	ft.	ft. tons.	ft. tons.	ft.	ft. tons.	ft. tons
0	1300	8200	24·7	1413	2492	100·2	1525	1855	85·3
200	1277	7915	17·6	1369	2339	94·0	1467	1716	78·9
400	1255	7645	11·2	1327	2198	88·3	1409	1583	72·8
600	1234	7391	05·2	1286	2064	83·0	1356	1466	67·5
800	1215	7165	99·8	1248	1944	78·1	1307	1362	62·7
1000	1196	6946	94·5	1213	1837	73·8	1261	1268	58·3
1200	1178	6735	89·7	1180	1738	69·9	1217	1181	54·3
1400	1160	6531	85·3	1150	1651	66·3	1177	1105	50·8
1600	1143	6341	81·4	1122	1571	63·2	1141	1038	47·8
1800	1126	6154	77·7	1097	1502	60·4	1108	979	45·0
2000	1109	5971	74·4	1074	1440	57·9	1078	927	42·6
2200	1093	5799	71·5	1052	1381	55·5	1053	884	40·7
2400	1077	5630	68·9	1032	1329	53·4	1030	846	38·9
2600	1062	5474	66·5	1014	1283	51·6	1009	812	37·3
2800	1047	5322	64·4	996	1238	49·8	990	782	36·0
3000	1032	5169	62·4	980	1199	48·2	973	755	34·7
3200	1018	5030	60·6	965	1162	46·7	958	732	33·7
3400	1004	4892	59·2	952	1131	45·5	945	712	32·8
3600	991	4766	57·7	940	1103	44·3	934	696	32·0
3800	978	4642	56·4	930	1080	43·4	924	681	31·3
4000	966	4529	55·2	920	1056	42·5	916	669	

	Gauge of fuze-hole.	ing length of ren range.†	Remarks.
	ORDN		
Time,	General Service.	2,* and if	Painted red. — M.L. TIME FUZES ARE NOT AT PRESENT USED WITH COMMON SHELL FIRED FROM R.M.L. GUNS OF 7-IN. AND UPWARDS, IN THE L.S.‖
	do.	and add— 1	
	do.	 2	
		 3	
Percu	do.		The R.L. percussion fuze Mark II. is suited for all B.L. shell of G.S. gauge, and all R.M.L. guns up to the 80-pr. The Mark I. is suited to the 7 and 9-pr. R.M.L. only.
	do.		
	ORDN		
Time,	General Service.	2,* and if	Painted red.
	do.	and add— 1	
	do.	 2	
		 3	
Percu	do.		
,,	do.		
,,	Field Service.		
Time,	do.		Not used in land service.
	ORDNA		
Time	Common.	e range.*	
	do.	e range.*	
	General Service.		
	do.		
	Mortar.	ge.*	For ranges below 750 yards, double the range plus 10.
	Common.	ge.*	
Perc	do.		
	General Service.		

is fuzes for R.O., denote ole numbers denote ½ seconds, the decimals ½ seconds.
rs and the time of flight ways ignite with small charges.

h fuzes for high-angle fire tillery.